Missouri Department of Natural Resources
Water Protection Program

Bacteria
Total Maximum Daily Load (TMDL)

for

Creve Coeur Creek
St. Louis County, Missouri

DRAFT

(This page intentionally left blank)

Total Maximum Daily Load (TMDL) for Creve Coeur Creek
Pollutant: *Escherichia coli*

Name:
Creve Coeur Creek

Location:
St. Louis County

Nearby Cities:
Chesterfield and Maryland Heights

12-digit Hydrologic Unit Code (HUC):
103002000703 – Creve Coeur Creek

Water Body Identification Number (WBID) and Hydrologic Class:[1]
WBID 1703 – Class C

Designated uses:[2]
Livestock and wildlife protection (LWP)
Protection of warm water habitat (WWH)
Human health Protection (HHP)
Whole body contact recreation category B (WBC-B)

Other designations:
Metropolitan no-discharge stream[3]

Use that is Impaired:
Whole body contact recreation category B (WBC-B)

Length and location of impaired segment:[4]
3.8 miles, from Creve Coeur Lake to Section 6, Township 45N, Range 5E

Universal Transverse Mercator [Zone 15 north] coordinates:
E: 718439, N: 4287491 to E: 718183, N: 4283164

Pollutant on 2012 303(d) List:
Escherichia coli, or E. coli bacteria

1 For hydrologic classes see 10 CSR 20-7.031(1)(F). Class P streams maintain flow during drought conditions. Class C streams may cease flow during dry periods, but maintain permanent pools that support aquatic life. Class E streams have ephemeral surface flow.
2 For designated uses see 10 CSR 20-7.031(1)(C) and 10 CSR 20-7.031 Table H.
3 For metropolitan no-discharge stream designations, see 10 CSR 20-7.031 Table F.
4 The water body segment length is revised in 10 CSR 20-7.031 Table H, effective October 2009. This revision reflects a more accurate measurement of length. The location and the starting and ending points of this segment have not changed. This length differs from what is presented on the 2012 303(d) list of impaired waters.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

1. Introduction

The Missouri Department of Natural Resources in accordance with Section 303(d) of the federal Clean Water Act is establishing this Creve Coeur Creek Total Maximum Daily Load, or TMDL. This water quality-limited segment in St. Louis County is included on Missouri's 2012 303(d) List of impaired waters. The listing of Creve Coeur Creek as impaired by *Escherichia coli* bacteria was approved by the U.S. Environmental Protection Agency on July 11, 2012. The department's 303(d) submittal to EPA cited urban runoff and storm sewers as likely sources of the impairment. This report addresses the Creve Coeur Creek bacteria impairment by establishing a TMDL for *Escherichia coli*, or *E. coli*. Data analyses conducted to support this listing and TMDL development indicate that *E. coli* bacteria are present at concentrations that result in exceedances of Missouri's water quality criterion for the whole body contact recreation category B designated use.

Section 303(d) of the federal Clean Water Act and Chapter 40 of the Code of Federal Regulations (CFR) Part 130 requires states to develop TMDLs for waters not meeting designated uses. The TMDL process quantitatively assesses the impairment factors so that states can establish water quality-based controls to reduce pollution and restore and protect the quality of their water resources. The purpose of a TMDL is to determine the pollutant loading a water body can assimilate without exceeding state water quality standards. Missouri's Water Quality Standards at 10 CSR 20-7.031 consist of three components: designated uses, water quality criteria to protect those uses and an antidegradation policy. The TMDL establishes the pollutant loading capacity necessary to meet the water quality standards established for each water body based on the relationship between pollutant sources and instream water quality conditions. A TMDL consists of a wasteload allocation, a load allocation, and a margin of safety. The wasteload allocation is the fraction of the total pollutant load apportioned to point sources. The load allocation is the fraction of the total pollutant load apportioned to nonpoint sources. The margin of safety is a percentage of the TMDL that accounts for any uncertainty associated with the model assumptions as well as any data inadequacies.

Creve Coeur Creek was first listed as impaired by bacteria in 2006 due to data showing elevated *E. coli* concentrations. The state's 2012 listing methodology determines a water body to be impaired by bacteria if the geometric mean in a given recreational season exceeds the water quality criteria in any of the last three years for which there are available data. This listing methodology also states that at least five samples are needed during the recreational season in order to determine impairment. Data meeting these listing methodology criteria were available in 2007, 2008, and 2009. *E. coli* counts exceeding the state criterion were observed in 2008 and 2009.

In addition to bacteria, Creve Coeur Creek is also on the 2012 303(d) List as impaired by chloride and low dissolved oxygen. Separate TMDLs will be developed at a future date to address these other pollutants. The department's TMDL development schedule is available online at dnr.mo.gov/env/wpp/tmdl/wpc-tmdl-progress.htm.

2. Background

Creve Coeur Creek is an urban stream located in eastern Missouri in St. Louis County. The impaired portion of Creve Coeur Creek extends 3.8 miles upstream from Creve Coeur Lake and is identified in the Missouri Use Designation Dataset as water body identification number, or WBID, 1703 (Figure 1).[5] Creve Coeur Creek is located in the Moreau/Loutre Ecological Drainage Unit[6], or EDU, in the Ozark aquatic subregion[7] (MoRAP 2005a). Creve Coeur Creek originates in northwestern Ballwin, Mo. and flows in a generally northeastern direction for approximately 11.4 miles before entering Creve Coeur Lake in Maryland Heights. From Creve Coeur Lake, the stream flows for another 2.1 miles where it enters the Missouri River. The watershed of Creve Coeur Creek, WBID 1703, drains approximately 27.6 square miles.

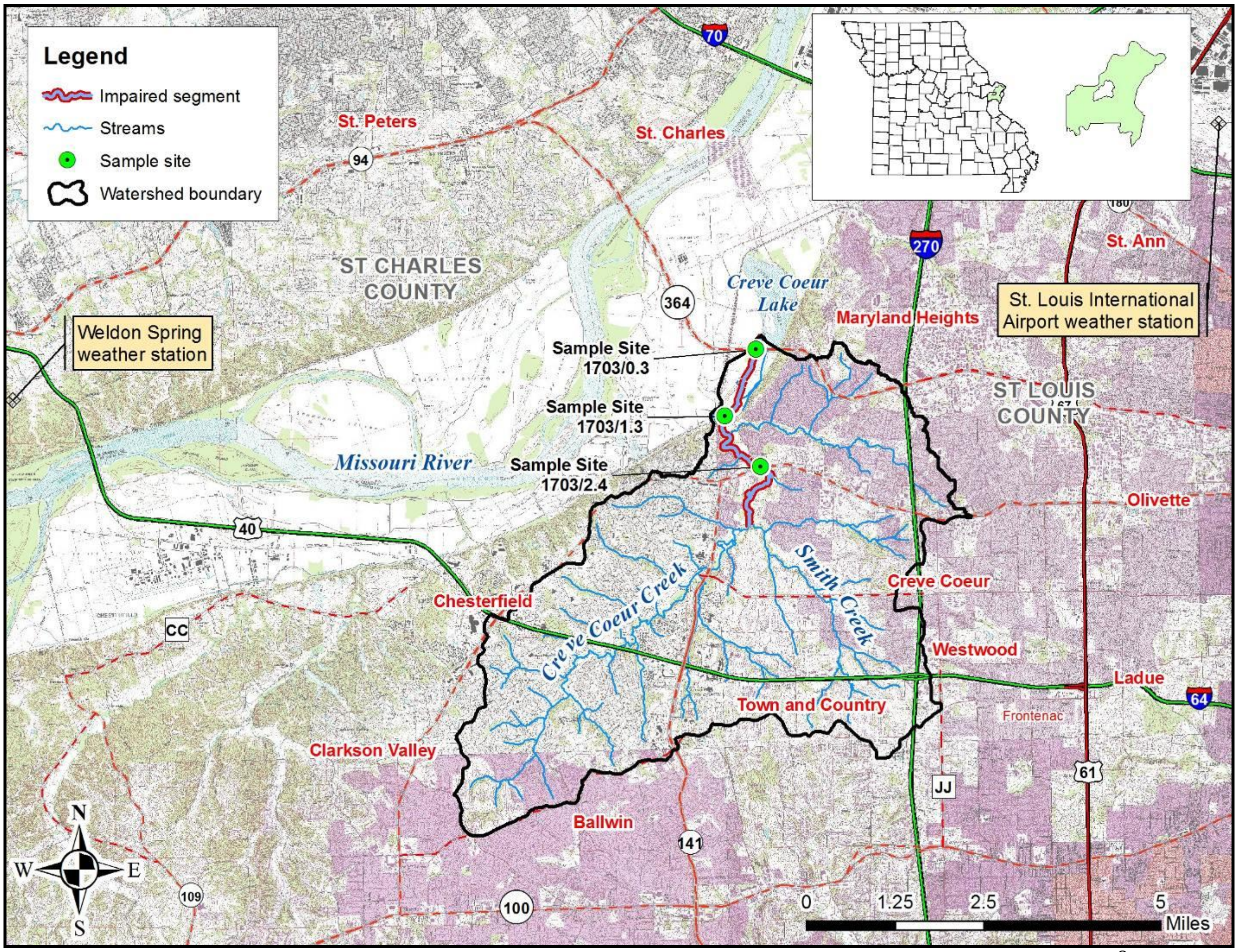

Figure 1. Location of the Creve Coeur Creek watershed in St. Louis County, Missouri[8]

2.1 Geology, Physiography and Soils

Creve Coeur Creek is located within the Lower Missouri River subbasin, identified by the 8-digit hydrologic unit code, or HUC, 10300200.[9] This subbasin covers over 1,500 square miles from the

[5] The Missouri Use Designation Dataset documents the names and locations of the state's rivers, streams, lakes and reservoirs, which have been assigned designated uses. See 10 CSR 20.7031 (1)(P).
[6] Ecological Drainage Units are groups of watersheds having generally similar biota, geography, and climatic characteristics (USGS 2009).
[7] Missouri's three aquatic subregions are the Central Plains, the Mississippi Alluvial Basin, and the Ozark (MoRAP 2005a).
[8] Sampling sites from downstream to upstream (north to south): 1703/0.3 Creve Coeur Cr. at Mill Bridge Rd., 1703/1.3 Creve Coeur Cr. at Creve Coeur Mill Rd., 1703/2.4 Creve Coeur Cr. at Highway 340

Missouri River's confluence with the Gasconade River to its confluence with the Mississippi River. The Lower Missouri River basin contains portions of the Claypan Prairie, the River Hills, the Osage/Gasconade Hills, the Central Plateau, and the Middle Mississippian Alluvial Plain level IV ecoregions.[10] The Creve Coeur Creek watershed is contained almost entirely within the River Hills ecoregion. This area is a transition zone between the Central Irregular Plains and the Ozark Highlands. Key characteristics of the River Hills are loess-covered hills and numerous karst features (Chapman et al. 2002). Karst features in the Creve Coeur Creek watershed include 46 sinkholes (MoDNR 2010).

The impaired segment of Creve Coeur Creek has a stream length of 3.8 miles. The topographic relief along this segment is generally 19 feet along the stream valley up to 206 feet in the adjoining uplands. The elevation of the impaired segment ranges from approximately 459 feet above sea level (upstream) to 439 feet (downstream). The elevation of the impaired watershed ranges from approximately 731 feet (upstream) to 439 feet (downstream) (CARES 2005).

Soils in the Creve Coeur Creek watershed are varied, but can be grouped based on similar characteristics. Table 1 provides a summary of hydrologic soil groups in the Creve Coeur Creek watershed. Hydrologic soil groups categorize soils by their runoff potential. A soil's hydrologic soil group relates to the rate at which water enters the soil profile under thoroughly wetted, bare soil surface conditions. Group A represents soils with the highest rate of infiltration and the lowest runoff potential under these conditions and Group D represents the group with the lowest rate of infiltration and highest potential for runoff. The dominant soil group in the Creve Coeur Creek watershed is Group D, which covers approximately 74 percent of the watershed. In general, soils within this group have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. Soils within the second most represented group, Group B, cover approximately 17 percent of the watershed. Group B soils include silt loam and loam that have moderate infiltration rates. These soils consist of well-drained soils with moderately fine to moderately coarse textures. Group C soils, which includes sandy clay loam soils that have a moderately fine to fine structure account for the remaining 5 percent of rated soils in the watershed. These soils consist chiefly of soils with a layer that impedes downward movement of water (NRCS 2007). The remaining area of the watershed was not rated. Areas not rated are typically areas of open water, quarries or landfills. In the Creve Coeur Creek watershed, most areas not rated in a hydrologic soil group are classified as the soil type Urban land, upland, 0 to 5 percent slopes. This soil type is defined as being 90 percent urban land and has no specific associated soil data given (NRCS 2010). Figure 2 shows the location and distribution of these hydrologic soil groups throughout the watershed.

---

[9] Watersheds are delineated by the U.S. Geological Survey using a nationwide system based on surface hydrologic features. This system divides the country into 2,270 8-digit hydrologic units (USGS and NRCS 2011).
[10] Ecoregions are areas with similar ecosystems and environmental resources. A level I ecoregion is a coarse, broad category, while a level IV is a more defined grouping.

Table 1. Hydrologic soil groups in the Creve Coeur Creek watershed (NRCS 2009)

Hydrologic Soil Group	*Creve Coeur Creek*	
	Sq. Miles	*Percentage*
Group A	0	0 %
Group B	4.88	17.65 %
Group C	1.53	5.52 %
Group D	20.42	73.85 %
Not Rated	0.82	2.98 %

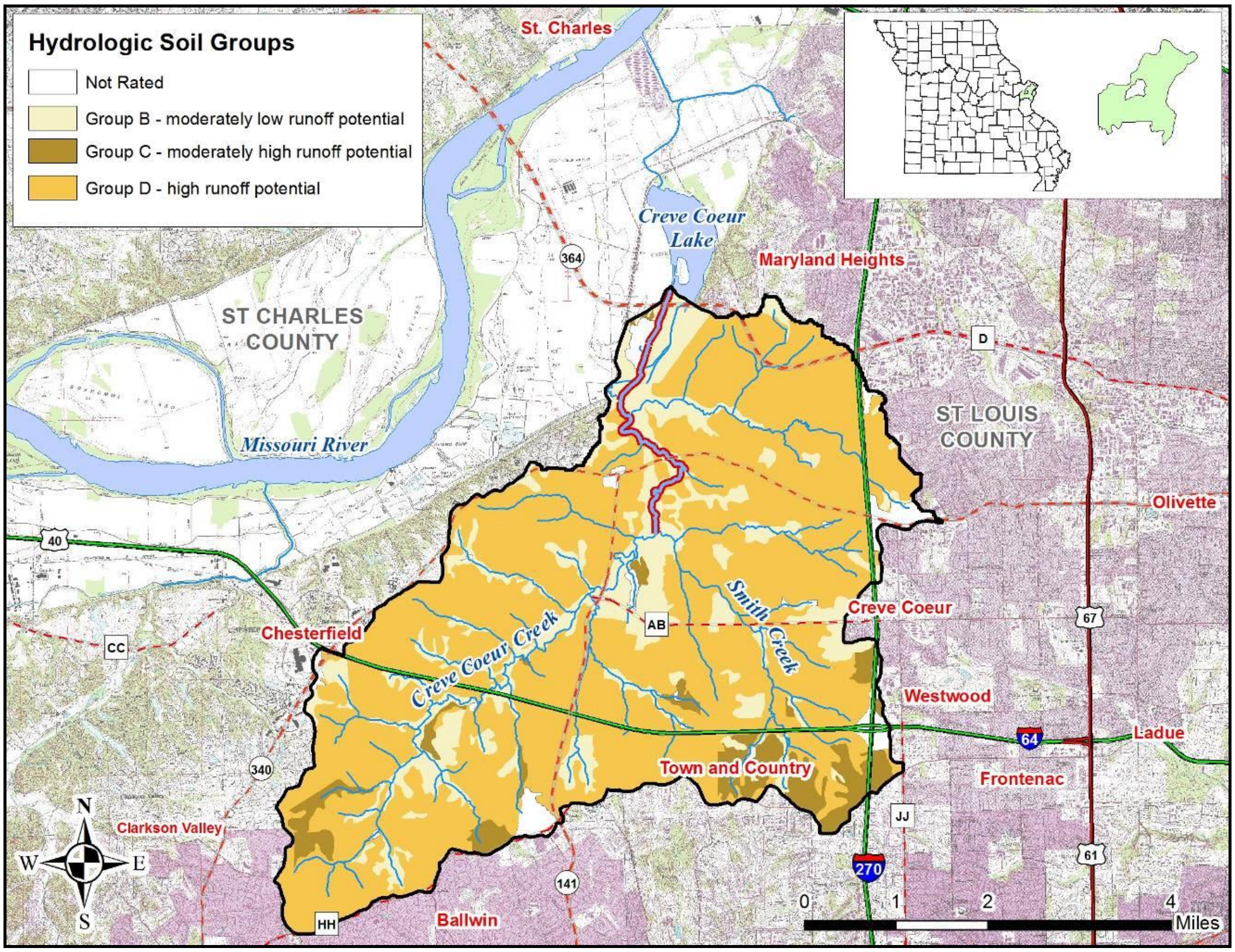

Figure 2. Hydrologic soil groups in the Creve Coeur Creek watershed (NRCS 2009)

The hydrologic soil groups within the Creve Coeur Creek watershed are comprised of 34 individual soil types. The five most abundant of these soil types in the watershed are shown in Table 2. Four of these five most abundant soil types in the Creve Coeur Creek watershed are defined as being primarily urban land with an accompanying soil type, and cover approximately 69.75 percent of the watershed. These four soil types are derived from loess parent materials and are silt loams with a silt clay loam component. The most abundant is the Urban land-Harvester complex, 2 to 9 percent slopes. This soil type is defined as 50 percent urban land and 40 percent Harvester and similar soils. This soil is found along interfluves and hill slopes, is moderately well drained and not prone to frequent flooding. Urban land-Harvester complex, 9 to 20 percent slopes, is the second most abundant soil type in the Creve Coeur Creek watershed. It is defined as being composed of 55 percent urban land and 25 percent Harvester and similar soils. This soil type is found primarily on hill slopes and is moderately well drained and not prone to frequent flooding. The third most abundant soil type in the watershed is Urban land-Harvester complex, karst, with 2 to 9 percent slopes. This soil type is defined as being 60 percent urban land and karst, and 30 percent Harvester and similar soils. This soil type is found along hill slopes, sinkholes and interfluves. It is moderately well drained and is not prone to frequent flooding. The fourth most abundant soil type is Urban land-Harvester complex, karst, 9 to 20 percent slopes. This soil is defined as being 55 percent urban land and karst as well as 30 percent Harvester and similar soils. This soil is moderately well drained and is typically found along hill slopes or sinkholes. The fifth most abundant soil type in the Creve Coeur Creek watershed is Wilbur silt loam, 0 to 2 percent slopes, frequently flooded, which is comprised of 80 percent Wilbur and similar soils. This soil is moderately well drained and is found in flood plains and is therefore prone to frequent flooding (NRCS 2010).

Table 2. Abundant soil types in the Creve Coeur Creek watershed (NRCS 2009)

Soil Type	***Acres***	***Percent***
Urban land-Harvester complex, 2 to 9 percent slopes	5,577	31.52 %
Urban land-Harvester complex, 9 to 20 percent slopes	3,994	22.58 %
Urban land-Harvester complex, karst, 2 to 9 percent slopes	1,966	11.11 %
Urban land-Harvester complex, karst, 9 to 20 percent slopes	803	4.54 %
Wilbur silt loam, 0 to 2 percent slopes, frequently flooded	782	4.42 %

2.2 Rainfall and Climate

Weather stations provide useful information for developing a general understanding of climatic conditions in the watershed. The St. Louis International Airport and the National Weather Service's Weldon Spring weather station are the closest sources to the Creve Coeur Creek watershed with recent and available weather and climate data. Both of these stations are expected to provide climate data that are representative of the impaired watershed. The St. Louis International Airport weather station is located in St. Louis County about 9 miles northeast of the upstream end of the impaired segment between the municipalities of Bridgeton and Berkeley. The Weldon Spring weather station is located about 10.5 miles west of the upstream end of the impaired segment near the municipality of Weldon Spring Heights in St. Charles County. Both stations record daily precipitation, maximum and minimum temperatures, snowfall and snow depth data. The locations of these weather stations in relation to the Creve Coeur Creek watershed are shown in Figure 1.

Precipitation is an important factor related to stream flow and stormwater runoff events that can influence certain pollutant sources. The average annual precipitation and annual average minimum and maximum temperatures over the 30-year period from 1981 through 2010 are 40.92 inches and 47.8/66.1 degrees Fahrenheit (°F) for the St. Louis International Airport station and 42.47 inches and 43.5/65.5 °F for the Weldon Spring weather station (NOAA 2011). The 30-year climate data from these stations are summarized in Figure 3.

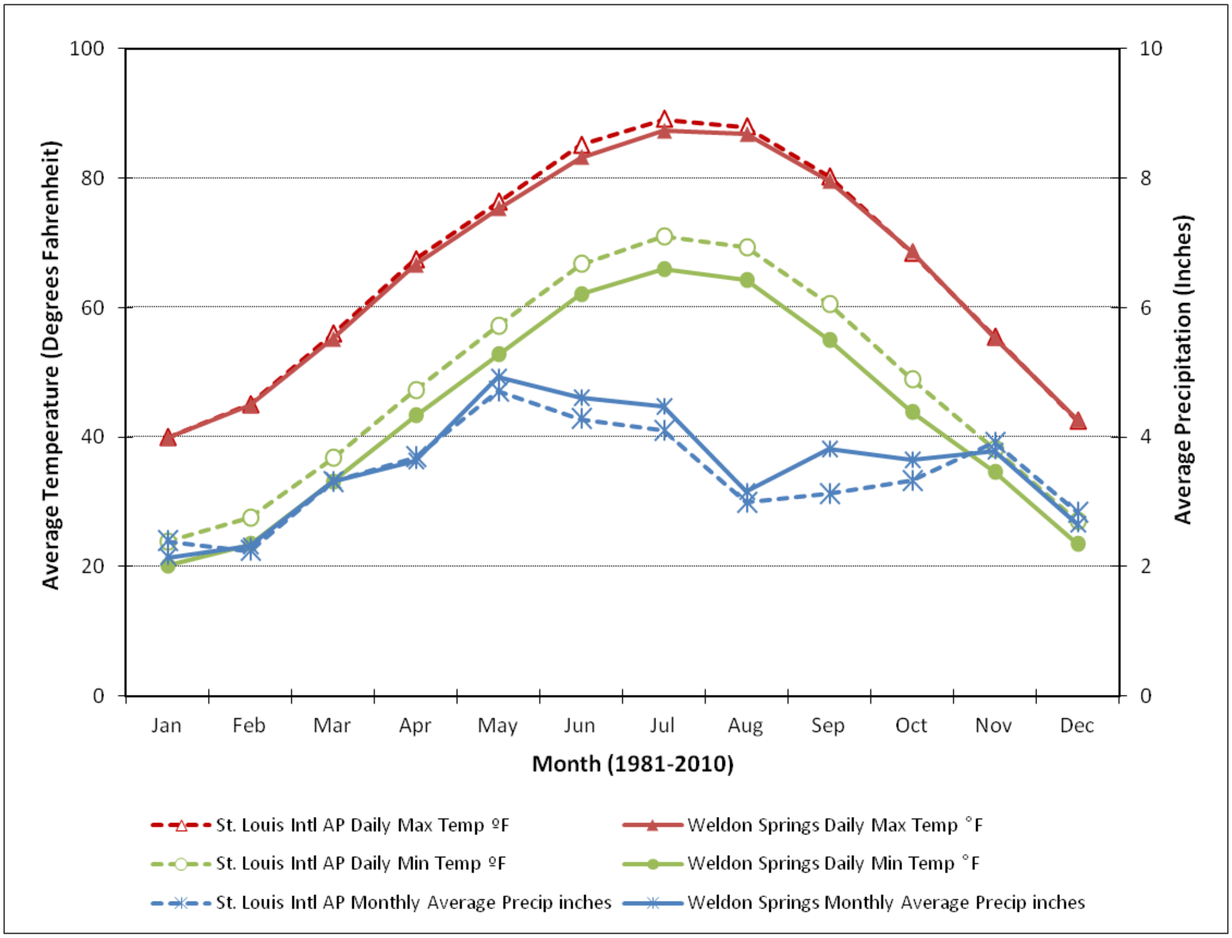

Figure 3. Thirty-year monthly temperature and precipitation averages for the St. Louis International Airport and Weldon Spring weather stations.

2.3 Population

St. Louis County covers an area of 523 square miles and, according to 2010 census data, has a population of 999,021 people (U.S. Census Bureau 2010). The population of the Creve Coeur Creek watershed is not directly available; however, using U.S. Census Bureau census block data from 2010, the population of the Creve Coeur Creek watershed was estimated to be approximately 62,645. This estimation was completed by using Geographic Information System, or GIS, software and superimposing the watershed boundary over a map of census blocks. Where the centroid of a census block fell within the watershed boundary, its total population was included in the total. If the centroid of the census block was outside the watershed boundary, then the population was excluded. The U.S. Census Bureau defines the entire area within the Creve Coeur Creek watershed as urban based primarily on population density as well as land use types that are part of the urban landscape (U.S. Census Bureau 2011). EPA defines this urban area as an entity requiring stormwater regulations through municipal separate storm sewer permits (EPA 2002).

Using 2000 census data and 12-digit hydrologic unit code watershed boundaries, EPA completed a similar analysis and determined that the Creve Coeur Creek watershed is an Environmental Justice watershed.[11] This determination was based on the area of the 12-digit watershed and the percentages of racial minority and low-income populations (Steve Schaff, EPA, email communication, June 30, 2011). Communities within an Environmental Justice watershed may qualify for financial and strategic assistance for addressing environmental and public health issues (EPA 2011a).

2.4 Land Use

Land use calculations are based on data from 2000 to 2004 at 30-meter resolution obtained from Thematic Mapper imagery (MoRAP 2005b). These calculations are presented in Table 3. Figure 4 graphically presents the available land use data for the Creve Coeur Creek watershed. The watershed is predominantly an urban environment, with areas categorized as urban or impervious accounting for over 69 percent of the watershed. Areas defined in the dataset as low-intensity urban comprise approximately 63 percent of the total area and account for the majority of the watershed's land use. Low-intensity urban is defined as vegetated urban environments with a low density of buildings. In the Creve Coeur Creek watershed, these areas are primarily residential areas. Areas categorized as high-intensity urban areas account for 0.79 percent of the watershed area and are defined as being vegetated urban environments with a high density of buildings. Areas of the watershed categorized as impervious account for about 6 percent of the watershed area. Impervious areas are defined in the land use dataset as areas with little, if any, vegetation, that are dominated by streets parking lots, and buildings. Although the land use dataset categorizes specific areas as impervious, impervious areas exist in all urban land use categories due to the presence of roads, parking lots, driveways, and rooftops. The Metropolitan St. Louis Sewer District, which is a public agency responsible for management of wastewater and some stormwater in the watershed, estimates that the total imperviousness of the watershed is around 27 percent (Kristol Whatley, Metropolitan St. Louis Sewer District, email communication, Aug. 6, 2012). This amount of imperviousness in the watershed is significant as stream degradation associated with imperviousness has been shown to first occur at about 10 percent imperviousness and to increase in severity as imperviousness increases (Arnold and Gibbons 1996; Schueler 1994).

Following low-intensity urban, the second most abundant land use type is grassland, which accounts for approximately 14 percent of the watershed area. Because this is an urban watershed, areas classified as grassland include golf courses, cemeteries, parks, school playgrounds and other open spaces not typically thought of as grassland or pasture. Forested and Woodland areas comprise about 12 percent of the watershed and are found primarily in riparian (streamside) areas. Together areas categorized as being wetland and open water account for 3 percent of the watershed area. Area classified as cropland account for less than 1 percent of the watershed, but is likely much less and probably nonexistent. A comparison of the available land use data with 2010 National Agriculture Imagery Program aerial imagery shows areas in the Creve Coeur Creek watershed categorized as cropland to be athletic fields and green spaces showing some degree of disturbance (USDA 2010). Herbaceous areas comprise three hundredths of a percent of the total watershed area.

[11] EPA defines Environmental Justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations and policies.

Table 3. Land use in the Creve Coeur Creek watershed (MoRAP 2005b)

Land Use Type	***Creve Coeur Creek***		
	Acres	***Sq. Miles***	***Percentage***
Impervious	1,048	1.64	5.92 %
High-Intensity Urban	140	0.22	0.79 %
Low-Intensity Urban	11,106	17.35	62.77 %
Row and Close-grown Crops	172	0.27	0.97 %
Grassland	2,463	3.85	13.92 %
Forest & Woodland	2,198	3.43	12.42 %
Herbaceous	5	0.01	0.03 %
Wetland	304	0.48	1.72 %
Open Water	256	0.40	1.45 %
Barren	0	0	0 %
Total:	17,692	27.65	99.99 %

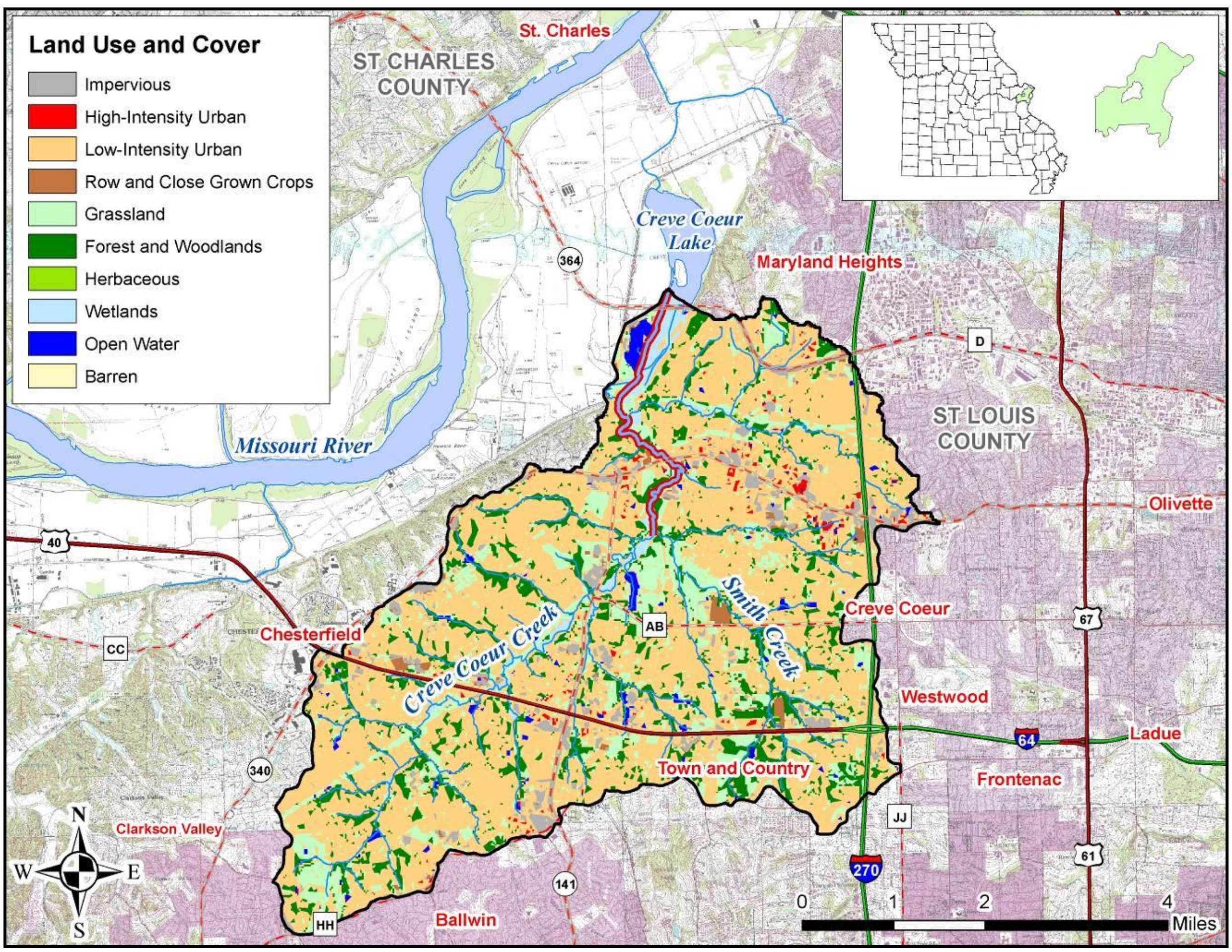

Figure 4. Land use in the Creve Coeur Creek watershed

2.5 Defining the Problem

A TMDL is needed for Creve Coeur Creek, because the department has determined that this stream is not meeting the state bacteria water quality criterion for whole body contact recreation category B (See Section 4). Data collected from Creve Coeur Creek by the U.S. Geological Survey, or USGS, and the Metropolitan St. Louis Sewer District show exceedances of the state's whole body contact recreation category B criterion of 206 *E. coli* counts per 100 milliliters of water (206/100mL). This assessment is based on the geometric mean of samples collected during the state's recreational season (April 1 through October 31). Bacteria data collected from Creve Coeur Creek within the last five years are expected to be the most representative of the stream's current condition. Table 4 and Figure 5 summarize bacteria data collected from Creve Coeur Creek during the 2006 – 2010 recreational seasons. Figure 6 summarizes all *E. coli* data by month for this same period. All available *E. coli* data for Creve Coeur Creek, including any data collected outside of the recreational season, is found in Appendix A.

Table 4. Recreational season *E. coli* data for Creve Coeur Creek (2006 – 2010)*

Year	*Sampling Events*	*Geometric Mean*	*Minimum*	*Maximum*	*WBC Category*†	*Criterion*	*Exceedance*‡
2006	9	616.63	79	5,800	B	206	Yes
2007	12	100.51	0.499	13,000	B	206	No
2008	5	290.04	64	990	B	206	Yes
2009	7	914.57	148	7,700	B	206	Yes
2010	2	1,785.39	520	6,130	B	206	--

* The units for all *E. coli* values are counts/100 mL of water. For calculation purposes, *E. coli* measurements recorded as a less than (<) value were halved.
† WBC = whole body contact recreation
‡ Years with fewer than five samples within the recreational season are not assessed against the whole body contact criterion.

High counts of *E. coli* may be an indication of fecal contamination and an increased risk of pathogen-induced illness to humans. *E. coli* are bacteria found in the intestines of humans and warm-blooded animals and are used as indicators of the risk of waterborne disease from pathogenic bacteria or viruses (EPA 1997). Infections due to pathogen-contaminated waters include gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases. To address these potential health risks, this TMDL targets instream bacteria levels using *E. coli* as the primary measurement parameter. Selection of *E. coli* as the numeric target enables the use of the highest quality data available and provides consistency with Missouri's water quality standards.

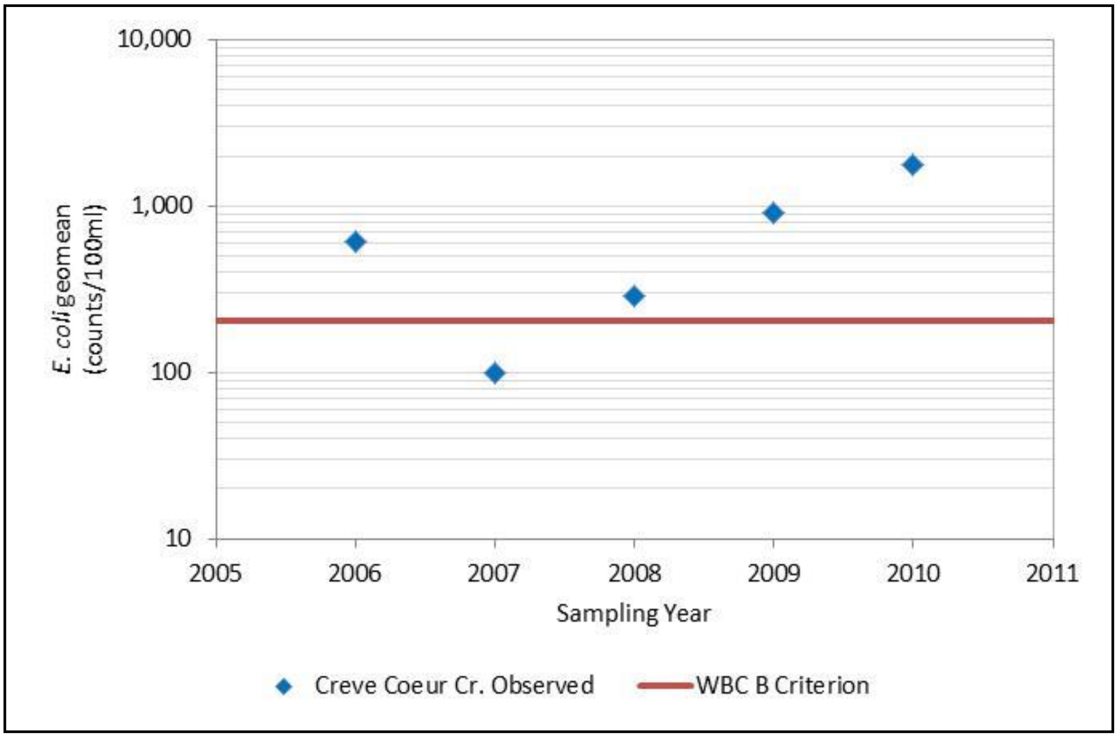

Figure 5. Recreational season geometric mean *E. coli* data (2006 – 2010)[12]

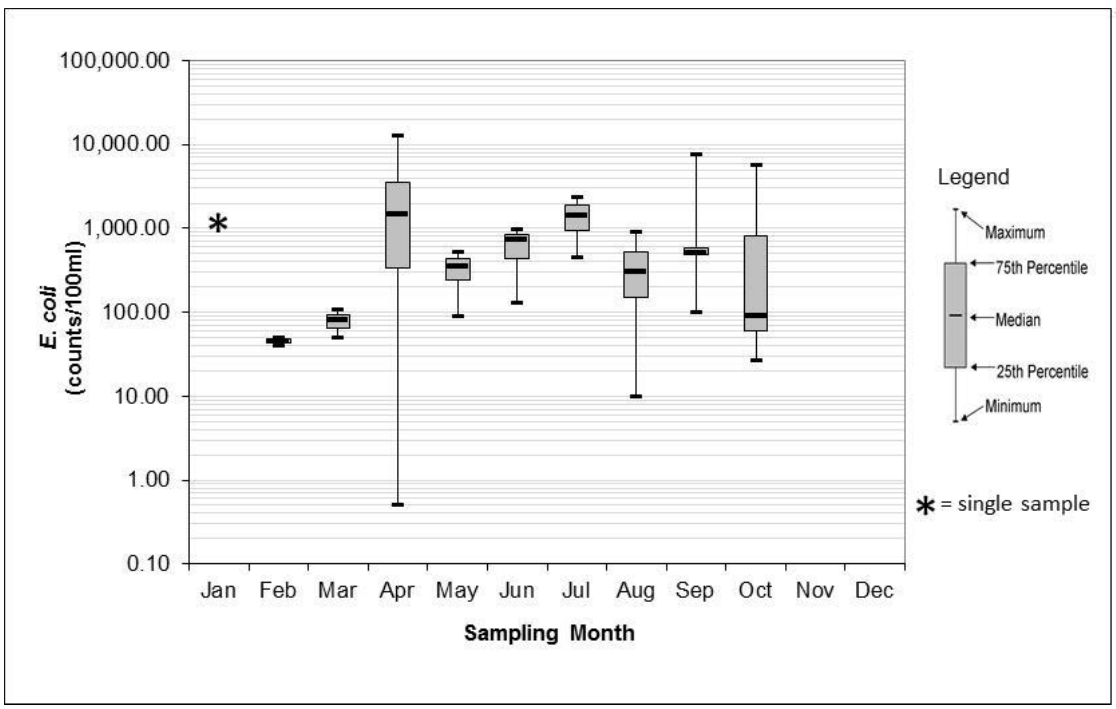

Figure 6. Monthly *E. coli* data for Creve Coeur Creek (2006 – 2010)

[12] WBC = Whole body contact recreation

3. Source Inventory and Assessment

Source inventory and assessment characterizes known, suspected and potential sources of pollutant loading to the impaired water body. Pollutant sources identified within the watershed are categorized and quantified to the extent that information is available. Sources of pollutants may be point (regulated) or nonpoint (unregulated) in nature.

3.1 Point Sources

Point sources are defined under Section 502(14) of the federal Clean Water Act and are typically regulated through the Missouri State Operating Permit program[13] and include any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. Under this definition, point sources include domestic and municipal wastewater treatment facilities, concentrated animal feeding operations, or CAFOs, stormwater discharges from municipal seperate storm sewer systems, illicit straight pipe discharges, and stormwater runoff from construction and industrial sites. Designated as a Metropolitan No-Discharge Stream, no water contaminant except uncontaminated cooling water, permitted stormwater discharges in compliance with permit conditions and excess wet-weather bypass discharges not interfering with beneficial uses may be discharged into the Creve Coeur Creek watershed.

At the time of this writing, the Creve Coeur Creek watershed contains 21 permitted facilities. Five of these facilities have general permits and the remaining 16 have stormwater permits. There are no facilities with site-specific permits in the Creve Coeur Creek watershed, nor are there any permitted CAFOs. Figure 7 shows the location of the permitted outfalls within the watershed.

[13] The Missouri State Operating Permit system is Missouri's program for administering the federal National Pollutant Discharge Elimination System (NPDES) program. The NPDES program requires all point sources that discharge pollutants to waters of the United States to obtain a permit.

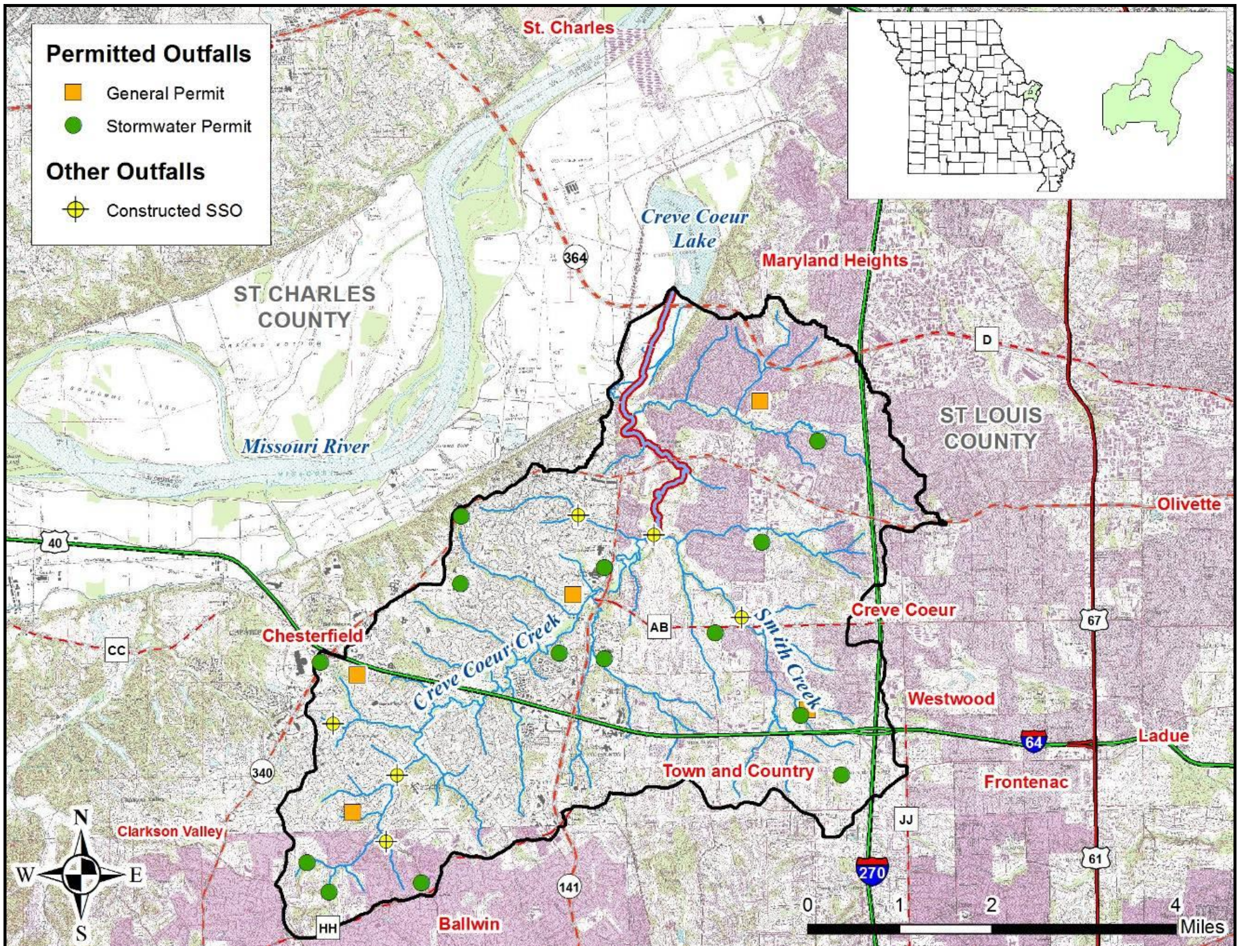

Figure 7. Outfall locations in the Creve Coeur Creek watershed (Oct. 10, 2012)[14, 15]

3.1.1 Municipal and Domestic Wastewater Permits

There are no municipal or domestic wastewater permitted facilities or outfalls in the Creve Coeur Creek watershed. However, the urban area within the watershed is serviced by a sanitary sewer system maintained by the Metropolitan St. Louis Sewer District. A sanitary sewer system is designed to carry household waste, which includes both greywater and sewage, to a wastewater treatment facility; in this case, the Missouri River wastewater treatment facility, permit no. MO-0004391, located about 2 miles north of the watershed. Although the treatment facility is located outside the watershed, the presence of the sewerage system infrastructure within the Creve Coeur Creek watershed is a potential source of bacteria due to possible overflows.

Sanitary sewer overflows are untreated or partially treated sewage releases from a sanitary sewer system. Overflows could occur for a variety of reasons including blockages, line breaks, sewer defects, lapses in sewer system operation and maintenance, inadequate sewer design and construction, power failures and vandalism. Sanitary sewer overflows can occur during either dry or wet weather and at any point in the collection system, including manholes. Such overflows are unpermitted and unauthorized by the federal Clean Water Act. Occurrences of sanitary sewer

[14] MS4 permits regulates the entire watershed area, permit no. MO-R040005 and MO-R040063
[15] SSO = sanitary sewer overflow

overflows can result in elevated bacteria concentrations (EPA 1996). One such occurrence of a sanitary sewer overflow occurred in the Creve Coeur Creek watershed on Aug. 24, 2011 when a sewer line broke and discharged about 215,000 gallons of sewage into Smith Creek, a tributary of Creve Coeur Creek (CBS 2011). In addition to unintended overflows, six constructed sanitary sewer overflows, installed to relieve the sanitary sewers from excess flow caused by inflow and infiltration of stormwater during high rain events, are located within the watershed (John R. Lodderhose, Metropolitan St. Louis Sewer District, email communication, August 22, 2011). All of these overflows are located upstream of the impaired segment (Figure 9). A USGS study of the sources of *E. coli* in metropolitan St. Louis area streams, including Creve Coeur Creek, estimated that about one-third of the measured, in-stream *E. coli* in St. Louis area streams originates from humans. The study also indicated that there is a correlation between *E. coli* densities and the number of upstream sanitary sewer overflows (USGS 2010). For these reasons, sanitary sewer overflows are considered significant potential contributors of *E. coli* to Creve Coeur Creek.

In addition to sanitary sewer overflows, combined sewer overflows are also present within some areas serviced by the Metropolitan St. Louis Sewer District. A combined sewer system collects both stormwater runoff and wastewater, including domestic sewage. These systems are designed not only to transport wastewater to treatment facilities, but also to discharge directly to a water body if its capacity is exceeded due to stormwater inputs. Combined sewer systems were an early sewer design and can be found in many older cities. As with sanitary sewer overflows, combined sewer overflows can result in periods of elevated bacteria concentrations in a water body due in large part to the discharge of domestic sewage as well as the runoff component from roofs, parking lots and residential yards and driveways. No combined sewer overflows exist within the Creve Coeur Creek watershed. Therefore, combined sewer overflows do not cause or contribute to the bacteria impairment of Creve Coeur Creek.

3.1.2 Industrial and Non-Domestic Wastewater Permits

There are no industrial or non-domestic wastewater facilities with site-specific permits in the Creve Coeur Creek watershed. Typically, industrial and non-domestic facilities discharge wastewater resulting from non-sewage generating activities and therefore are not expected to contribute significant bacteria loads.

3.1.3 General and Stormwater Permits

General and stormwater permits are issued based on the type of activity occurring and are meant to be flexible enough to allow for ease and speed of issuance, while providing the required protection of water quality. General and stormwater permits are issued to activities similar enough to be covered by a single set of requirements, and are designated with permit numbers beginning with “MO-G” or “MO-R” respectively. A summary of the general and stormwater permits in the Creve Coeur Creek watershed can be found in Table 5.

Table 5. General (MO-G) and stormwater (MO-R) permits in the Creve Coeur Creek watershed*

Permit No.	*Facility Name*	*Discharge Type*	*Receiving Stream*	*Permit Expires*
MO-G690052	Claymont Lake Estates Pond	Stormwater	Trib. Creve Coeur Cr.	3/13/2013
MO-G760044	Montessori Children House	Swimming pool drainage	Trib. Creve Coeur Cr.	4/9/2014
MO-G760066	Creve Coeur Racquet Club	Swimming pool drainage	Trib. Smith Cr.	4/9/2014
MO-G760117	Robinwood West Cid Community Center	Swimming pool drainage	Trib. Creve Coeur Cr.	4/9/2014
MO-G760120	Chesterfield City Hall	Swimming pool drainage	Trib. Creve Coeur Cr.	4/9/2014
MO-R040005	Metropolitan St. Louis Sewer District and co-permittees small MS4	Stormwater	--	6/12/2013
MO-R040063	Missouri Dept. of Transportation Small MS4	Stormwater	--	6/12/2013
MO-R80C464	Parkway School District	Stormwater	Creve Coeur Cr.	10/4/2012
MO-RA00217	Chesed Shel Emeth Cemetery	Stormwater	Trib. Creve Coeur Cr.	2/7/2017
MO-RA00294	Brooking Park Villas	Stormwater	Trib. Creve Coeur Cr.	2/7/2017
MO-RA00295	Schnucks	Stormwater	Trib. Creve Coeur Cr.	2/7/2017
MO-RA00306	Difani Estates	Stormwater	Trib. Creve Coeur Cr.	2/7/2017
MO-RA00332	Brunhaven	Stormwater	Trib. Creve Coeur Cr.	2/7/2017
MO-RA00646	The Villas at Meadowbrook	Stormwater	Trib. Creve Coeur Cr.	2/7/2017
MO-RA00652	St. Luke’s Hospital - CVICU	Stormwater	Trib. Creve Coeur Cr.	2/7/2017
MO-RA00657	Terra Bella – Lot 5	Stormwater	Trib. Creve Coeur Cr.	2/7/2017
MO-RA00830	Sunset Grove Estates	Stormwater	Trib. Creve Coeur Cr.	2/7/2017
MO-RA01273	Hyatt Place - Chesterfield	Stormwater	Trib. Creve Coeur Cr.	2/7/2017
MO-RA01451	The Villas at Woodland Creek	Stormwater	Trib. Creve Coeur Cr.	2/7/2017
MO-RA01704	Enclave Bellerive	Stormwater	Trib. Creve Coeur Cr.	2/7/2017
MO-RA01891	Missouri Baptist University	Stormwater	Smith Cr.	2/7/2017

***** Permitted dischargers in the Creve Coeur Creek watershed on Oct. 10, 2012

As noted in Table 5, there are two small municipal separate storm sewer system permits, or MS4 permits, in the Creve Coeur Creek watershed. MS4 permits address pollutant contributions from urban runoff. In general, urban runoff has been found to carry high levels of bacteria and can be expected to exceed water quality criteria for bacteria during and immediately after storm events in most streams throughout the country (EPA 1983). *E. coli* contaminated runoff can come from both heavily paved areas and from open areas where soil erosion is common (Burton and Pitt 2002). For these reasons, urban runoff is a significant potential contributor of bacteria to Creve Coeur Creek.

Bacterial inputs to streams from urban runoff can be caused by sanitary sewer overflows as discussed in Section 3.1.1 of this document, but also commonly results from residential and green space runoff carrying domestic and wild animal wastes. Birds, dogs, cats, and rodents have been documented as common sources of *E. coli* in urban stormwater (Burton and Pitt 2002). The USGS study specific to the sources of *E. coli* in metropolitan St. Louis streams discussed in Section 3.1.1 of this document estimated that in addition to the one third of the bacteria originating from human sources, approximately 10 percent of the *E. coli* originated from dogs and 20 percent from geese (USGS 2010). Another component of urban runoff is runoff originating from highway corridors. The Federal Highway Administration published research showing that runoff from highway corridors may also contain bacteria. Sources of *E. coli* to highway areas identified in the study include bird droppings, soil, and vehicles carrying livestock and stockyard wastes (FHWA 1984). However, due to differences in the origins of bacteria from highway systems as opposed to other urban areas, it is likely that bacteria contributions from highway corridors are smaller than those contributions from portions of the watershed where residential areas dominate and contributions from pet waste, sanitary sewer overflows, or onsite wastewater treatment systems are more likely.

Stormwater discharges of urban runoff within the entire Creve Coeur Creek watershed are regulated through MS4 permits. For this reason, urban stormwater runoff is considered a point source for this TMDL. Although stormwater discharges are untreated, small MS4 permit holders must develop, implement, and enforce stormwater management plans to reduce the contamination of stormwater runoff and prohibit illicit discharges. These plans must include measurable goals, must be reported on annually, and must meet six minimum control measures. These six minimum control measures are public education and outreach, public participation and involvement, illicit discharge detection and elimination, construction site runoff control, post-construction runoff control, and pollution prevention. Entities within the Creve Coeur Creek watershed that are regulated under the MS4 permits noted in Table 5 include the Missouri Department of Transportation and the Metropolitan St. Louis Sewer District and its co-permittees, which include St. Louis County and the municipalities of Maryland Heights, Chesterfield, Creve Coeur, Town and Country, and Ballwin.

Regarding the remaining general and non-MS4 stormwater permits in Table 5, the department assumes activities in the watershed will be conducted in compliance with all permit conditions, including monitoring and discharge limitations. It is expected that compliance with these permits will result in bacterial loadings at or below applicable targets. For these reasons, these facilities are not expected to cause or contribute to the bacterial impairment of Creve Coeur Creek. If at any time the department determines that the water quality of streams in the watershed is not being adequately protected, the department may require the owner or operator of the permitted site to obtain a site-specific operating permit, per 10 CSR 20-6.010(13)(C).

3.1.4 Illicit Straight Pipe Discharges

Illicit straight pipe discharges of household waste are also potential point sources of bacteria. These sources are illegal and unpermitted discharges straight into streams or land areas and are different from illicitly connected sewers. However, there are no specific data on the number or presence of illicit straight pipe discharges of household waste in the Creve Coeur Creek watershed. Due to the presence of a sewerage system throughout the watershed, illicit straight pipe discharges are not expected to be significant contributors of *E. coli* to Creve Coeur Creek. Illicit discharge detection and elimination is one of the six minimum control measures required by an

MS4 permit. Such sources are therefore expected to be detected and eliminated in accordance with permitted conditions.

3.2 Nonpoint Sources

Nonpoint source pollution refers to pollution coming from diffuse, non-permitted sources that typically cannot be identified as entering a water body at a single location. They include all other categories of pollution not classified as being from a point source, and are exempt from department permit regulations as per state rules at 10 CSR 20-6.010(1)(B)1. These sources involve stormwater runoff from non-regulated areas and are minor or negligible under low-flow conditions. Typical nonpoint sources of pollution that have the potential to influence water quality include various sources associated with runoff from agricultural and non-MS4 permitted urban areas, onsite wastewater treatment systems, and riparian corridor conditions.

3.2.1 Agricultural Runoff

Stormwater runoff from lands used for agricultural purposes is often a source of bacterial loading to water bodies. Activities associated with agricultural land uses that may contribute bacteria to a water body include manure fertilization of croplands or pastures, and livestock grazing. However, as noted in Section 2.4, agricultural land in the Creve Coeur Creek watershed is virtually nonexistent. Less than 1 percent of the land use area within the watershed was classified as cropland and from recent aerial imagery these areas were found to be athletic fields or disturbed green spaces. For this reason, bacterial loading from cropland is not a likely contributor to the impaired condition of Creve Coeur Creek.

Bacterial inputs from livestock are also unlikely to contribute to the water body impairment. Although approximately 14 percent of the watershed area was classified as grassland, due to the urban nature of the watershed these areas are often cemeteries, parks, athletic fields or schoolyards where livestock animals are not likely to be grazing. However, although agricultural livestock production is not likely to contribute bacteria to Creve Coeur Creek, open green spaces within urban watersheds may still contribute bacteria via stormwater runoff contaminated by wildlife and domestic pet waste (Section 3.1.3). Runoff from all areas of the Creve Coeur Creek watershed is regulated through MS4 permits and is considered a point source for purposes of this TMDL.

3.2.2 Urban Runoff (non-MS4 permitted areas)

Stormwater runoff from urban areas not having MS4 permits is considered a nonpoint source. In the Creve Coeur Creek watershed, stormwater runoff falls within the jurisdiction of two MS4 permits. Therefore, for purposes of this TMDL, urban runoff within the Creve Coeur Creek watershed is considered a potential point source contributor of *E. coli* to Creve Coeur Creek. For this reason, no nonpoint urban runoff sources have been identified that are likely to be contributing to the bacteria impairment of Creve Coeur Creek. See Section 3.1.3 of this document for a more detailed discussion of urban runoff contributions and MS4 permitting.

3.2.3 Onsite Wastewater Treatment Systems

When properly designed and maintained, onsite wastewater treatment systems (e.g., home septic systems) should not serve as a source of contamination to surface waters; however, onsite wastewater treatment systems do fail for a variety of reasons. When these systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration), there can be adverse effects to surface water quality (Horsley and Witten 1996). Failing onsite wastewater treatment systems are known to be sources of bacteria, which can reach nearby streams through surface runoff and groundwater flows, thereby contributing bacteria loads under either wet or dry weather conditions. Onsite wastewater treatment systems may contribute bacteria to Creve Coeur Creek either directly or as a component of MS4-permitted stormwater.

The exact number of onsite wastewater treatment systems in the Creve Coeur Creek watershed is unknown, however such systems are known to exist in areas of the county developed prior to the sewerage systems serviced by the Metropolitan St. Louis Sewer District (Jack Fischer, St. Louis County Public Works, personal communication, June 6, 2011). Although septic system installations and repairs within St. Louis County require a permit, the county database cannot distinguish between work pertaining to onsite wastewater treatment systems and work pertaining to sanitary sewers because they are classified the same (Jack Fischer, St. Louis County Public Works, personal communication, Jan. 31, 2011). The Metropolitan St. Louis Sewer District maintains parcel and billing information that can be used to estimate the number of parcels in the watershed without a sewer connection. The majority of parcels in the watershed, approximately 99 percent, do have a sewer connection. Nonsewered or suspected nonsewered parcels in the watershed may include parcels with houses or other structures on them as well as parcels comprised entirely of green space. These parcels may have onsite wastewater systems on them. The Metropolitan St. Louis Sewer District confirms that less than 1 percent of the parcels in the Creve Coeur Creek watershed, approximately 176 parcels, are not connected to a sewer. However, is not known if any onsite systems exist on these parcels. An additional 0.2 percent of the parcels in the watershed, approximately 47 parcels, are suspected of not having a sewer connection. (Kristol Whatley, Metropolitan St. Louis Sewer District, email communication, Aug. 6, 2012).

As stated in Section 3.1.1 of this document, the Creve Coeur Creek watershed is serviced by the Metropolitan St. Louis Sewer District's Missouri River wastewater treatment facility, located about 2 miles north of the watershed. Due to the availability of this sewer system and a St. Louis County ordinance requiring that a sewer connection to a building be made when a sanitary sewer line is within 200 feet of the property, many onsite wastewater treatment system eliminations have likely been made. The consent decree established as part of the *United States of America and the State of Missouri, and Missouri Coalition for the Environment Foundation v. Metropolitan St. Louis Sewer District,* No. 4:07-CV-1120 also requires the implementation of a supplemental environmental project to decommission some septic tanks to low-income residents within the Metropolitan St. Louis Sewer District's service area. This project could aid in further reducing the number of septic tanks within the watershed, however overall reductions are dependent upon availability of funding for this supplemental project.[16]

EPA's Spreadsheet Tool for Estimating Pollutant Load website estimates the failure rate of onsite wastewater treatment systems in St. Louis County as being 39 percent (EPA 2010a). A more recent study conducted by the Electric Power Research Institute suggests that up to 50 percent of

[16] Any references to implementation of a supplemental environmental project shall include the following reference: "This project was undertaken in connection with the settlement of an enforcement action, *United States of America and the State of Missouri, and Missouri Coalition for the Environment Foundation v. Metropolitan St. Louis Sewer District,* No. 4:07-CV-1120-CEJ, taken on behalf of the U.S. Environmental Protection Agency, State, and the Coalition under the Clean Water Act" (John R. Lodderhose, Metropolitan St. Louis Sewer District, email communication, Oct. 24, 2012).

onsite wastewater treatment systems may be failing (EPA 2010b; EPRI 2000). Despite the lack of specific data showing that onsite wastewater treatment systems are a significant problem in the Creve Coeur Creek watershed, the available failure rate data suggests that onsite wastewater treatment systems in the watershed are potential contributors of bacteria to Creve Coeur Creek either directly or as a component of MS4 stormwater. However, due to the overall urban nature of the watershed, the number of onsite wastewater systems present in the watershed is expected to be low.

3.2.4 Riparian Corridor Conditions

Riparian corridor conditions can have a strong influence on instream water quality. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal and assimilation of pollutants from runoff. Therefore, a stream with good riparian cover is better able to moderate the impacts of high pollutant loads than a stream with poor or no riparian cover. However, in the case of bacteria, vegetated areas may be additional sources of the impairment due to inputs from pets and wildlife.

Table 6 presents land use data for the riparian corridor within the Creve Coeur Creek watershed. This analysis used the land use data calculated in Section 2.4 and defined the riparian corridor as including a 30-meter area on each side of all streams included in the National Hydrography Dataset 1:24,000-scale flowline.[17] As can be seen in Table 6, the riparian corridor of Creve Coeur Creek is predominantly urban and forested. Land classified as low-intensity urban comprises over 38 percent of the riparian corridor. Runoff from low-intensity urban areas, such as residential areas, can contribute bacteria loading to a water body from pet or wild animal wastes. For this reason, the riparian corridor conditions in the watershed are likely to contribute to the bacteria impairment of Creve Coeur Creek. Together, vegetated areas categorized as grassland and forest and woodland account for over 45 percent of the Creve Coeur Creek riparian corridor. In rural areas, grassland areas may provide higher bacterial loading than forest and woodland areas due to the presence of livestock. However, due to the highly urbanized environment of the Creve Coeur Creek watershed, livestock inputs are not likely to be occurring. However, bacterial inputs from these areas may still occur from pets and wildlife since, as previously noted in Section 2.4, areas categorized as grassland in the Creve Coeur Creek watershed are, in many cases, parks, cemeteries, and playgrounds. Areas within the riparian corridor of Creve Coeur Creek are within the urban area described by EPA as requiring MS4 permit regulations (see Section 2.3). Therefore, for purposes of this TMDL, stormwater runoff from these areas is considered a regulated point source (see Section 3.1.2).

[17] The National Hydrography Dataset is digital surface water data for geographic information systems (GIS) for use in general mapping and in the analysis of surface-water systems. Available URL: http://nhd.usgs.gov

Table 6. Land use data for the Creve Coeur Creek watershed riparian buffer, 30-meter

Land Use Type	*Acres*	*Square Miles*	*Percent*
Impervious	29	0.05	1.92 %
High-Intensity Urban	7	0.01	0.47 %
Low-Intensity urban	582	0.91	38.16 %
Row and close-grown crops	7	0.01	0.44 %
Grassland	209	0.33	13.68 %
Forest and woodland	490	0.77	32.11 %
Open water	69	0.11	4.53 %
Barren	0	0	0 %
Herbaceous	1	0	0.06 %
Wetlands	132	0.21	8.63 %
Total:	1,526	2.4	100 %

4. Applicable Water Quality Standards and Numeric Target

The purpose of developing a TMDL is to identify the pollutant loading that a water body can assimilate and still achieve water quality standards. Water quality standards are therefore central to the TMDL development process. Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III). Water quality standards consist of three components: designated uses, water quality criteria, and an antidegradation policy.

4.1 Designated Uses

Designated uses are the uses for a water body identified in the state water quality standards that must be maintained in accordance with the federal Clean Water Act. The following designated uses have been assigned to Creve Coeur Creek:

- Livestock and wildlife protection (LWP)
- Protection of warm water habitat (WWH)
- Human health protection (HHP)
- Whole body contact recreation category B (WBC-B)

The use impaired by bacteria in this stream is the protection of whole body contact recreation category B. Whole body contact recreation includes activities in which there is direct human contact with surface water that results in complete body submergence, thereby allowing accidental ingestion of the water as well as direct contact to sensitive body organs, such as the eyes, ears and nose. Category A waters include water bodies that have been established as public swimming areas and waters with documented existing whole body contact recreational uses by the public. Category B applies to waters designated for whole body contact recreation, but are not contained within category A.

4.2 Water Quality Criteria

Water quality criteria are limits on particular chemicals or conditions in a water body to protect particular designated uses. Water quality criteria can be expressed as specific numeric criteria or as general narrative statements.

In Missouri's water quality standards at 10 CSR 20-7.031(5)(C), specific numeric criteria are given for the protection of the whole body contact recreation use. For category B waters, *E. coli* counts, measured as a geometric mean, shall not exceed 206 counts/100 mL of water during the recreational season. The state's recreational season is defined as being from April 1 to October 31.

4.3 Antidegradation Policy

Missouri's Water Quality Standards include the EPA "three-tiered" approach to antidegradation, and may be found at 10 CSR 20-7.031(3).

Tier 1 – Protects existing uses and a level of water quality necessary to maintain and protect those uses. Tier 1 provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after Nov. 28, 1975, the date of EPA's first Water Quality Standards Regulation.

Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economic and social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing uses.

Tier 3 – Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges and waters of exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality.

Waters in which a pollutant is at, near or exceeds the water quality criteria are considered in Tier 1 status for that pollutant. Therefore, the antidegradation goals for Creve Coeur Creek are to restore the streams' water quality to levels that meet water quality standards.

4.4 Numeric Target for TMDL Development

As noted in Section 4.2 of this document, Missouri's water quality standards include a specific numeric *E. coli* water quality criterion of 206 *E. coli* counts per 100 mL of water, measured as a geometric mean during the recreational season for waters designated with the whole body contact recreation category B use. The concentration value of 206 counts/100 mL will serve as the numeric target for TMDL development. This targeted concentration will be expressed as a daily load that varies by flow using a load duration curve. Achieving this targeted load will also result in achieving the state's whole body contact recreation category B water quality criterion.

5. Modeling Approach

For Creve Coeur Creek, the load duration approach was used. When stream flow gage information is available, a load duration curve is useful in identifying and differentiating between storm-driven and steady-input sources. The load duration approach may be used to provide a visual representation of stream flow conditions under which pollutant criteria exceedances have occurred, to assess critical conditions, and to estimate the level of pollutant load reduction necessary to meet the surface water quality targets for bacteria in the stream (Cleland 2002; Cleland 2003).

A load duration curve also identifies the maximum allowable daily pollutant load for any given day as a function of the flow occurring that day, which is consistent with the Anacostia Ruling (*Friends of the Earth, Inc., et al v. EPA,* No 05-5010, April 25, 2006) and EPA guidance in response to this ruling (EPA 2006; EPA 2007a). EPA guidance recommends that all TMDLs and associated pollutant allocations be expressed in terms of daily time increments, and suggests that there is flexibility in how these daily increments may be expressed. This guidance indicates that where pollutant loads or water body flows are highly dynamic, it may be appropriate to use a load duration curve approach, provided that such an approach "identifies the allowable daily pollutant load for any given day as a function of the flow occurring on that day." In addition, for targets that are expressed as a concentration of a pollutant, it may be appropriate to use a table or graph to express individual daily loads over a range of flows as a product of a water quality criterion multiplied by stream flow and a conversion factor (EPA 2006).

Average daily flow data for Creve Coeur Creek were directly available from June 11, 1997 to Jan. 2, 2011, from the USGS gaging station USGS 06935890 Creve Coeur Creek near Creve Coeur, Mo (Figure 8). Flow data from this gage were adjusted to the impaired watershed based on the ratio of the impaired watershed areas to the gage drainage area of 27.7 square miles. A detailed discussion of the methods used to develop the bacteria load duration curve is presented in Appendix B.

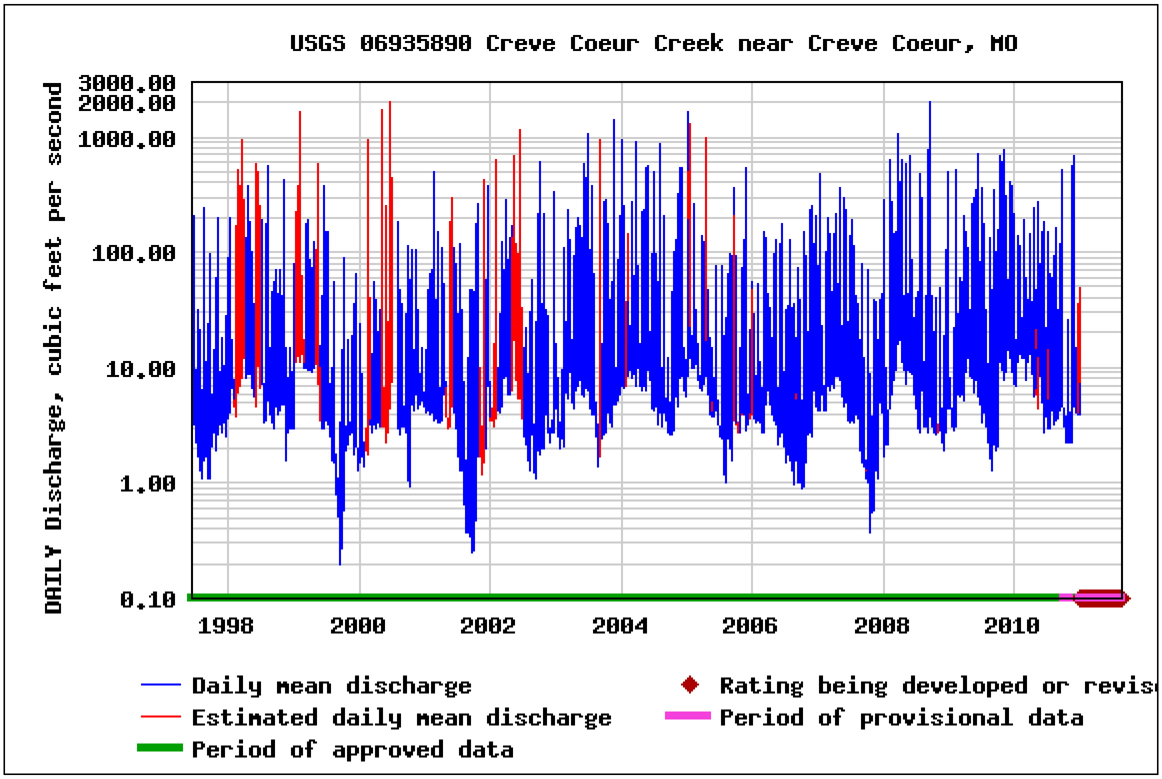

Figure 8. 1997 – 2011 flow data from Creve Coeur Creek (USGS 2011)

6. Calculating Loading Capacity

A TMDL calculates the loading capacity of a water body and allocates that load among the various pollutant sources in the watershed. The loading capacity is the maximum pollutant load that a water body can assimilate and still attain water quality standards. It is equal to the sum of the wasteload allocation, load allocation and the margin of safety, and can be expressed as the equation:

$$TMDL = LC = \sum WLA + \sum LA + MOS$$

where LC is the loading capacity, ∑WLA is the sum of the wasteload allocations, ∑LA is the sum of the load allocations, and MOS is the margin of safety.

According to 40 CFR §130.2(i), TMDLs can be expressed in terms of mass per time, toxicity or other appropriate measures. For Creve Coeur Creek, bacteria TMDLs are expressed as *E. coli* counts per day using a load duration curve. To develop a load duration curve, the TMDL target concentration is multiplied by the flow and a conversion factor to generate the maximum allowable load at different flows. Figure 9 is the bacteria TMDL load duration curve calculated for Creve Coeur Creek. The y-axis describes bacteria loading as counts per day, which are plotted against the flow duration intervals on the x-axis, which represent the frequency for which a particular flow is met or exceeded. The load duration curve presented in Figure 9 represents the loading capacity as a solid curve over the range of flows. Bacteria measurements collected from Creve Coeur Creek during the recreational season are plotted as blue points. Geometric means of the bacteria data exceeding the TMDL are plotted as green triangles within a specific flow condition (i.e., high flows). Flow condition ranges presented in Figure 9 illustrate general base flow and surface-runoff conditions consistent with EPA guidance on using load duration curves for TMDL development (EPA 2007b). Table 7 presents the TMDL loading capacity and the TMDL allocations for Creve Coeur Creek over a range of flows.

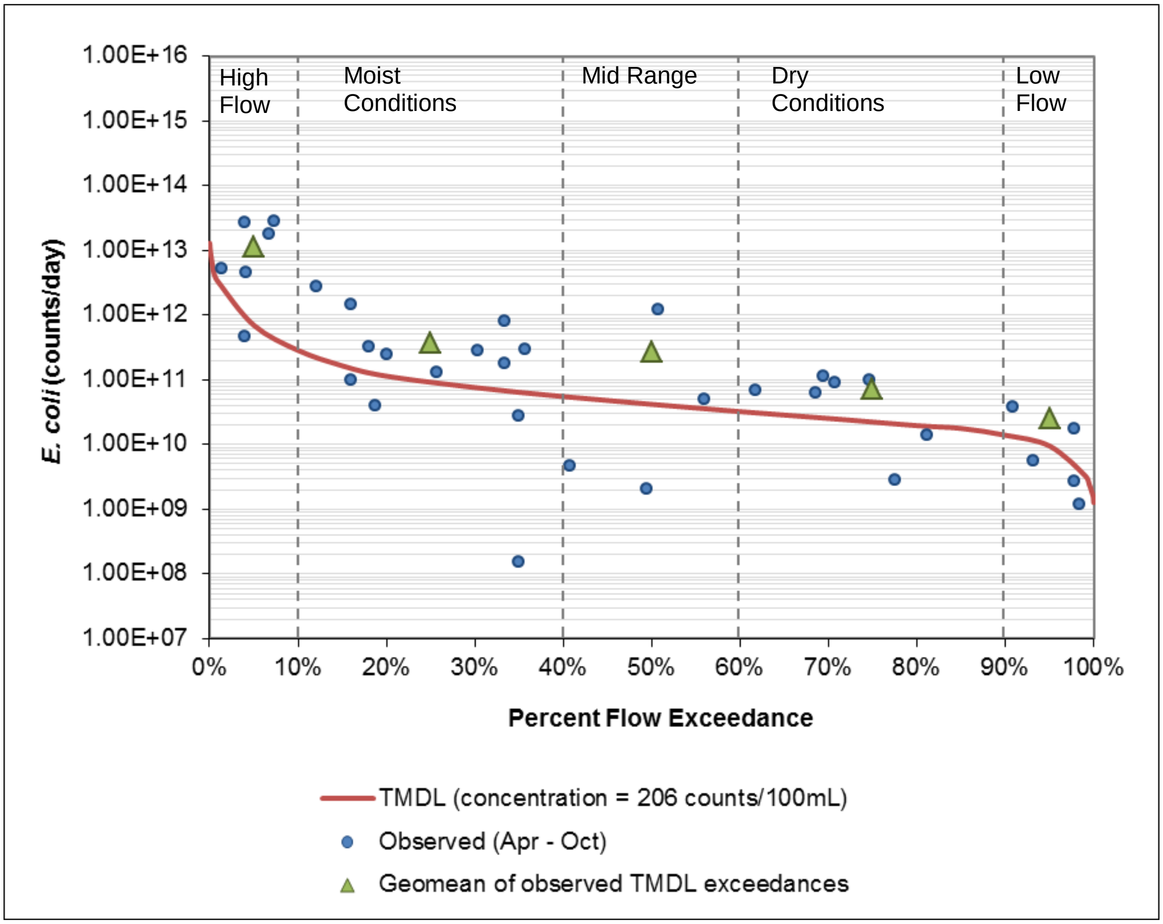

Figure 9. Creve Coeur Creek load duration curve

Table 7. *E. coli* TMDL for Creve Coeur Creek over a range of flows*

Percentile Flow Exceedance	*Flow (cfs)*	*Targets Based on concentration of 206/100mL*			
		TMDL (counts/day)	*MS4 WLA (counts/day)*	*LA (counts/day)*	*MOS (counts/day)*
90	2.8	1.39E+10	1.25E+10	0	1.39E+09
75	4.4	2.22E+10	2.00E+10	0	2.22E+09
50	8.3	4.18E+10	3.76E+10	0	4.18E+09
25	17.6	8.87E+10	7.98E+10	0	8.87E+09
10	56.6	2.85E+11	2.57E+11	0	2.85E+10

* cfs = cubic feet per second; WLA = wasteload allocation; LA = load allocation; MOS = margin of safety

7. Wasteload Allocation (Point Source Load)

The wasteload allocation is the allowable amount of the pollutant load that can be allocated to existing or future point sources. Typically, point sources are permitted with limits for a given pollutant that are the most stringent of either technology-based effluent limits or water quality-based effluent limits. Technology-based effluent limits are based upon the expected capability of a treatment method to reduce the pollutant to a certain concentration. Water quality-based effluent limits represent the most stringent concentration of a pollutant that a receiving stream can assimilate without violating applicable water quality standards at a specific location. Wasteload allocations for Creve Coeur Creek over a range of flows are presented in Table 7.

As noted in Sections 3.1.1 and 3.1.2 of this document, there are no site-specific permitted point sources in the Creve Coeur Creek watershed that may contribute to *E. coli* loading. A sewerage system is present in the watershed; however, this system discharges from a treatment works facility located outside of the watershed. Even so, sanitary sewer overflows still occur and are likely significant contributors of *E. coli* to Creve Coeur Creek and its tributaries. However, these discharges are unpermitted and not authorized under the Clean Water Act. For this reason, constructed sanitary sewer overflows in the Creve Coeur Creek watershed are given a wasteload allocation of zero. Elimination of bacteria loading from these sources will be accomplished through the requirements of the Metropolitan St. Louis Sewer District's consent decree.

Stormwater runoff is another potential contributor of bacteria loading to Creve Coeur Creek. In the Creve Coeur Creek watershed, stormwater runoff is regulated through MS4 permits. Bacterial contributions from MS4 permitted entities are precipitation dependent and vary with flow. Because the entire watershed area is regulated through MS4 permits and there are no other permitted facilities found to cause or contribute to the impairment, and because there is insufficient data to adequately disaggregate the MS4 wasteload allocation among the permitted entities, all wasteload allocations are aggregated and allocated to the total MS4 area. For this TMDL, the MS4 wasteload allocation is the remainder of the loading capacity after allocations to the margin of safety (Table 7).

Table 5 lists other facilities with general or non-MS4 stormwater permits; however, the department assumes activities in the watershed will be conducted in compliance with all permit conditions, including monitoring and discharge limitations. It is expected that compliance with these permits will result in bacterial loading at or below applicable targets. For these reasons, these facilities are not expected to cause or contribute to the bacterial impairment of Creve Coeur Creek. If at any time the department determines that the water quality of streams in the watershed is not being adequately protected, the department may require the owner or operator of the permitted site to obtain a site-specific operating permit per 10 CSR 20-6.010(13)(C). The wasteload allocation for these general and stormwater permitted dischargers is zero.

The wasteload allocations listed in this TMDL do not preclude the establishment of future point sources of bacterial loading in the watershed. Any future point sources should be evaluated against the TMDL and the range of flows, which any additional bacterial loading will affect.

8. Load Allocation (Nonpoint Source Load)

The load allocation is the allowable amount of the pollutant load that can be assigned to nonpoint sources and includes all existing and future nonpoint sources, as well as natural background contributions (40 CFR §130.2(g)). Nonpoint sources identified in this TMDL to be potential contributors of bacteria include onsite wastewater treatment systems. If functioning properly, these systems should not be contributing to the impaired condition of Creve Coeur Creek. Stormwater runoff within the watershed is regulated by MS4 permits. Therefore, for purposes of this TMDL, stormwater runoff is considered a point source and stormwater contributions are considered in the wasteload allocation. For these reasons, load allocations are set to zero at all flows.

9. Margin of Safety

A margin of safety is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems. The margin of safety is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the margin of safety can be achieved through two approaches:

- Explicit - Reserve a portion of the loading capacity as a separate term in the TMDL.
- Implicit - Incorporate the margin of safety as part of the critical conditions for the wasteload allocation and the load allocation calculations by making conservative assumptions in the analysis.

The margin of safety for this TMDL is an explicit 10 percent as shown in Table 7. Furthermore, bacterial decay or die off was not accounted for in the establishment of this TMDL. This conservative assumption provides an additional implicit margin of safety. Together, the explicit and implicit margins of safety account for any modeling uncertainties and data inadequacies, such as potential loading contributions from bacteria resuspension.

10. Seasonal Variation

Missouri’s water quality criteria for the protection of whole body contact recreation are applicable during the recreational season defined as being from April 1 to October 31. The TMDL load duration curve in Figure 9 represents stream flow under all conditions. For this reason, the *E. coli* targets and allocations established in this TMDL will be protective throughout the recreational season. The advantage of a load duration curve approach is that all flow conditions are considered and the constraints associated with using a single-flow critical condition are avoided.

11. Monitoring Plans

The department has not yet scheduled post-TMDL monitoring for Creve Coeur Creek. Post-TMDL monitoring is usually scheduled and carried out by the department approximately three years after the approval of the TMDL or in a reasonable period following completion of permit compliance schedules and the application of new effluent limits, or following significant implementation activities such as removal of constructed sanitary sewer overflows. The department will routinely examine water quality data collected by other local, state and federal entities in order to assess the effectiveness of TMDL implementation. Such entities may include the USGS, EPA, the Missouri Department of Health and Senior Services, the Missouri Department of Conservation, county health departments and the Metropolitan St. Louis Sewer District. In addition, certain quality-assured data collected by universities, municipalities, private companies and volunteer groups may potentially be considered for monitoring water quality following TMDL implementation.

12. Reasonable Assurance

Section 303(d)(1)(C) of the federal Clean Water Act requires that TMDLs be established at a level necessary to implement applicable water quality standards. As part of the TMDL process, consideration must be given to the assurances that point and nonpoint source allocations will be achieved and water quality standards attained. Where TMDLs are developed for waters impaired by point sources only, reasonable assurance is derived from the National Pollutant Discharge Elimination System permitting program through discharge permits issued with effluent limits as stringent as necessary to meet water quality standards (CWA Section 301(b)(1)(C)). For impaired waters, these discharge permits must be issued so that effluent limits are consistent with the assumptions and requirements of approved TMDL wasteload allocations (40 CFR 122.44(d)(1)(vii)(B)). The department has the authority to issue and enforce Missouri State Operating Permits for point source discharges. Inclusion of effluent limits in a state operating permit and requiring that effluent and instream monitoring be reported to the department should provide reasonable assurance that instream water quality standards will be met. The Clean Water Act at Section 402(p)(3)(B)(iii) provides that stormwater permits for MS4 areas contain controls to reduce pollutants to the “maximum extent practicable” and such other provisions as the EPA administrator or the state determine appropriate. Under this provision, the permitting authority has the discretion to include requirements for reducing pollutants in stormwater discharges as necessary for compliance with water quality standards (EPA 2010c). This permitting discretion provides reasonable assurance that appropriate pollutant reductions from MS4 permitted entities will occur.

The consent decree established as part of the *United States of America and the State of Missouri, and Missouri Coalition for the Environment Foundation v. Metropolitan St. Louis Sewer District*, No. 4:07-CV-1120 requires specific eliminations and reductions of point sources in the Metropolitan St. Louis Sewer District’s service area, for which Creve Coeur Creek is a part. This court-approved decree will provide an additional reasonable assurance of bacteria reductions in Creve Coeur Creek from point sources over a 23-year period (EPA 2011b).

Where a TMDL is developed for waters impaired by both point and nonpoint sources, point source wasteload allocations must be stringent enough so that in conjunction with the water body's other loadings (i.e., nonpoint sources) water quality standards are met. This generally occurs when the TMDL’s combined nonpoint source load allocations and point source wasteload allocations do not exceed the water quality standards-based loading capacity and there is reasonable assurance that the TMDL's allocations can be achieved. Reasonable assurance that nonpoint sources will meet their allocated amount in the TMDL is dependent upon the availability and implementation of nonpoint source pollutant reduction plans, controls or BMPs within the watershed. If BMPs or other nonpoint source pollution controls make more stringent load allocations practicable, then wasteload allocations can be made less stringent. Thus, the TMDL process provides for nonpoint source control tradeoffs (40 CFR 130.2(i)). When a demonstration of nonpoint source reasonable assurance is developed and approved for an impaired water body, additional pollutant allocations for point sources may be allowed provided water quality standards are still attained. When a demonstration of nonpoint source reasonable assurance does not exist, or it is determined that nonpoint source pollutant reduction plans, controls or BMPs are not feasible, durable, or will not result in the required load reductions, allocation of greater pollutant loading to point sources cannot occur.

A variety of grants and loans may be available to assist watershed stakeholders with developing and implementing watershed plans, controls and practices to meet the required wasteload and load allocations in the TMDL and demonstrate additional reasonable assurance.

13. Public Participation

EPA regulations require that TMDLs be subject to public review (40 CFR 130.7). The water quality-limited segment of Creve Coeur Creek in St. Louis County is included on Missouri's EPA-approved 2012 303(d) List of impaired waters. A 45-day public notice and comment period for this TMDL was from June 22, 2012 through Aug. 6, 2012. Any comments received and the department's responses to those comments will be maintained on file with the department and on the Creve Coeur Creek TMDL record webpage at dnr.mo.gov/env/wpp/tmdl/1703-creve-coeur-ck-record.htm. In addition to the public notice and comment period, the department hosted a meeting to provide information to the public regarding the TMDL process and the overall goals of this and other bacteria TMDLs developed for impaired streams in St. Louis County. The public meeting was held on Sept. 12, 2012 from 6 pm to 8 pm at the Daniel Boone Branch of the St. Louis County Library at 300 Clarkson Road in Ellisville. The meeting agenda, the department's presentation, and an attendance sheet are available online on the Creve Coeur Creek TMDL record webpage.

Due to comments received during the 2012 public comment period and revisions made to the state's water quality standards in 2014, changes to the TMDL were necessary. For this reason, a second public comment period was held from May 23, 2014 to Aug. 21, 2014. Groups that directly received the public notice announcement include the Missouri Clean Water Commission, the Missouri Water Quality Coordinating Committee, the Missouri Department of Conservation, the Missouri Department of Transportation, the St. Louis County Soil and Water Conservation District, the Metropolitan St. Louis Sewer District, the St. Louis County Department of Health, St. Louis County Public Works, the St. Louis County council, the University of Missouri Extension, the Missouri Coalition for the Environment, Stream Team volunteers living in or near the watershed, the Missouri Stream Team Watershed Coalition, any affected permitted entities, the nine state legislators representing areas within the watershed and any other individual or group who submitted comments during the first public comment period in 2012. For both public comment periods, the department posted the notice, the water body TMDL information sheets and this TMDL document on the department website, making them available to anyone with access to the Internet. Announcements of the public notice periods were also issued through a press release.

14. Administrative Record and Supporting Documentation

An administrative record on the Creve Coeur Creek TMDL has been assembled and is being kept on file with the Missouri Department of Natural Resources. It includes any studies, data and calculations on which the TMDL is based. This information is available upon request to the department at dnr.mo.gov/sunshine-form.htm. Any request for information on this TMDL will be processed in accordance with Missouri's Sunshine Law (Chapter 610, RSMO) and the department's administrative policies and procedures governing Sunshine Law requests. For more information on open record/Sunshine requests, please consult the department's website at dnr.mo.gov/sunshinerequests.htm.

15. REFERENCES

Arnold, C.L. and C.J. Gibbons. 1996. Impervious surface coverage: the emergence of a key environmental indicator. Journal of the American Planning Association 62.2

Burton, A.G. Jr. and R.E. Pitt. 2002. Stormwater effects handbook, a toolbox for watershed managers, scientists, and engineers. New York: CRC Press.

CARES (Center for Applied Research and Environmental Systems). 2005. 10-meter Digital Elevation Model [computer file]. Available URL: http://msdis.missouri.edu/

CBS St. Louis. (KMOX News Radio) 2011. Raw Sewage Spills into Smith Creek. [Online WWW] Available URL: http://stlouis.cbslocal.com/2011/08/24/raw-sewage-spills-into-smith-creek/ [Accessed 07 Dec. 2011].

Chapman, S.S., Omernik, J.M., Griffith, G.E., Schroeder, W.A., Nigh, T.A., and Wilton, T.F. 2002. Ecoregions of Iowa and Missouri (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,800,000).

Cleland, B.R., 2002. TMDL Development From the "Bottom Up" – Part II: Using Load Duration Curves to Connect the Pieces. Proceedings from the WEF National TMDL Science and Policy 2002 Conference.

Cleland, B.R., 2003. TMDL Development From the "Bottom Up" – Part III: Duration Curves and Wet-Weather Assessments. America's Clean Water Foundation, Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1983. Results of the Nationwide Urban Runoff Program – Executive Summary PB84-185545.

EPA (U.S. Environmental Protection Agency). 1996. Sanitary Sewer Overflows – What are they and how can we reduce them? EPA 832-K-96-001

EPA (U.S. Environmental Protection Agency). 1997. Volunteer Stream Monitoring: A Methods Manual. EPA 841-B-97-003

EPA (U.S. Environmental Protection Agency). 2002. Urbanized Area Maps. [Online WWW] Available URL: http://cfpub.epa.gov/npdes/stormwater/urbanmaps.cfm

EPA (U.S. Environmental Protection Agency). 2006. Establishing TMDL "daily" loads in light of the decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA, et al., No. 05-5015, (April 25, 2006), and implications for NPDES permits. [Online WWW] Available URL:

http://water.epa.gov/lawsregs/lawsguidance/owa/tmdl/dailyloadsguidance.cfm. [Accessed 23 Dec. 2011].

EPA (U.S. Environmental Protection Agency). 2007a. Options for Expressing Daily Loads in TMDLs. Office of Wetlands, Oceans & Watersheds. June 22, 2007.

EPA (U.S. Environmental Protection Agency). 2007b. An Approach for Using Load Duration Curves in the Development of TMDLs. EPA 841-B-07-006.

EPA (U.S. Environmental Protection Agency). 2010a. STEPL – Spreadsheet Tool for Estimating Pollutant Load. [Online WWW] Available URL: http://it.tetratech-ffx.com/stepl/ [Accessed 18 Feb. 2011].

EPA (U.S. Environmental Protection Agency). 2010b. STEPL – Spreadsheet Tool for Estimating Pollutant Load Frequently Asked Questions. [Online WWW] Available URL: http://it.tetratech-ffx.com/steplweb/Faq.htm [Accessed 18 Feb. 2011].

EPA (U.S. Environmental Protection Agency). 2010c. Revisions to the November 22, 2002 Memorandum "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs". Memorandum: Nov. 12, 2010.

EPA (U.S. Environmental Protection Agency). 2011a. Environmental Justice. [Online WWW] Available URL: http://www.epa.gov/environmentaljustice/basics/index.html [Accessed 25 July 2011].

EPA (U.S. Environmental Protection Agency). 2011b. U.S. vs. the Metropolitan St. Louis Sewer District – Consent Decree- Clean Water Act. Webpage. [Online WWW] Available URL: http://www.epa.gov/region07/enforcement_compliance/MSD_consent_decree_cwa.htm [Accessed 1 Nov. 2012].

EPRI (Electric Power Research Institute). 2000. Advanced On-Site Wastewater Treatment and Management Market Study: Volume 2: State Reports. TR-114870.

FHWA (Federal Highway Administration). 1984. Vol. I. Sources and Migration of Highway Runoff Pollutants – Executive Summary. FHWA/RD-84/057.

Horsley & Witten, Inc. 1996. Identification and Evaluation of Nutrient and Bacterial Loadings to Maquoit Bay, Brunswick, and Freeport, Maine.

MoDNR (Missouri Department of Natural Resources). 2010. Sinkholes. [computer file]. Available URL: ftp://msdis.missouri.edu/pub/state/st_sink_holes.zip

MoRAP (Missouri Resource Assessment Partnership). 2005a. A gap analysis for riverine ecosystems of Missouri. Final report, submitted to the USGS national gap analysis program. 1675pp.

MoRAP (Missouri Resource Assessment Partnership). 2005b. Land Use/Land Cover Data [ArcView shapefile]. Available from http://www.msdis.missouri.edu

NOAA (National Oceanic and Atmospheric Administration). 2011. NOAA Online Weather Data. [Online WWW] Available URL: http://www.weather.gov/climate/xmacis.php?wfo=lsx [Accessed 13 Sept. 2011].

NRCS (Natural Resources Conservation Service). 2007. National Engineering Handbook, Part 630 Hydrology, Chapter 7 Hydrologic Soil Groups.

NRCS (Natural Resources Conservation Service). 2009. Soil Survey Geographic Database (SSURGO). [computer file]. Available URL: http://SoilDataMart.nrcs.usda.gov

NRCS (Natural Resources Conservation Service). 2010. Web Soil Survey. Available URL: http://websoilsurvey.nrcs.usda.gov/ [Accessed 24 Jan. 2011]

Schueler, Tom. 1994. The importance of imperviousness. Watershed Protection Techniques. 1.3

U.S. Census Bureau (U.S. Department of Commerce). 2010. TIGER/Line Shapefile, 2010, 2010 state, Missouri, 2010 Census Block State-based [ArcView Shapefile]. Available URL: ftp://msdis.missouri.edu/pub/state/st_block10.zip

U.S. Census Bureau (U.S. Department of Commerce). 2011. Census 2000 Urban and Rural Classification [Online WWW] Available URL: http://www.census.gov/geo/www/ua/ua_2k.html

USDA (U.S. Department of Agriculture). 2010. National Agriculture Imagery Program (NAIP) [computer file]. Available URL: http://datagateway.nrcs.usda.gov

USGS (U.S. Geological Survey). 2009. Ecology-Ecological Drainage Units. [Online WWW] Available URL: http://nh.water.usgs.gov/projects/ct_atlas/tnc_edu.htm [Accessed 22 Oct. 2010].

USGS (U.S. Geological Survey). 2010. Occurrence and Sources of *Escherichia coli* in metropolitan St. Louis Streams, October 2004 through September 2007: U.S. Geological Survey Scientific Investigations Report 2010-5150.

USGS (U.S. Geological Survey). 2011. USGS Surface-Water Daily Data for Missouri. [Online WWW] Available URL: http://waterdata.usgs.gov/mo/nwis/dv? [Accessed 25 Aug. 2011].

USGS (U.S. Geological Survey) and NRCS (Natural Resources Conservation Service). 2011. Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD) (2^{nd} ed): US Geological Survey Techniques and Methods 11-A3, 62p. Available URL: http://pubs.usgs.gov/tm/tm11a3/

Appendix A

Creve Coeur Creek *E. coli* data

Sampling Organization[18]	Site Description[19]	WBID	UTM Easting	UTM Northing	Sampling Date	*E. coli* [20] (#/100mL)	Flow[21] (cfs)
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	6/14/2005	640	36.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	8/16/2005	4,000	37.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	9/14/2005	1,000	25.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	10/5/2005	100	3.2
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	11/8/2005	<100	4.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	2/1/2006	<100	6.1
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	3/1/2006	<100	3.6
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	8/15/2006	300	14.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	9/18/2006	500	21.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	10/16/2006	100	148.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	11/13/2006	<100	3.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	4/9/2007	18	8.5
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	8/15/2007	10	6.8
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	9/18/2007	100	1.8
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	10/23/2007	27	3.4
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	10/30/2007	45	0.84
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	4/1/2008	990	147.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	5/7/2008	400	415.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	5/20/2008	91	10.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	10/1/2008	890	4.1
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	10/15/2008	64	20.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	4/15/2009	441	18.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	6/10/2009	984	9.8
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	7/14/2009	2,380	11.0

[18] USGS = U.S. Geological Survey; MSD = Metropolitan St. Louis Sewer District
[19] See Figure 1 in Section 2 for sample site locations.
[20] For calculation purposes, less-than (<) values were halved. This methodology is consistent with the department's water quality assessment protocols.
[21] cfs = cubic feet per second.

Sampling Organization[18]	Site Description[19]	WBID	UTM Easting	UTM Northing	Sampling Date	*E. coli* [20] (#/100mL)	Flow[21] (cfs)
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	8/5/2009	148	3.1
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	9/22/2009	7,700	77.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	9/30/2009	583	2.1
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	10/12/2009	780	12.0
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	4/19/2010	6,130	6.5
MSD	Creve Coeur Cr. @Creve Coeur Mill Rd.	1703	717634	4285664	5/3/2010	520	11.0
MSD	Creve Coeur Cr.@ Mill Bridge Rd.	1703	718340	4285664	10/5/2004	<100	
MSD	Creve Coeur Cr.@ Mill Bridge Rd.	1703	718340	4285664	12/1/2004	400	
MSD	Creve Coeur Cr.@ Mill Bridge Rd.	1703	718340	4285664	1/11/2005	1,500	
MSD	Creve Coeur Cr.@ Mill Bridge Rd.	1703	718340	4285664	2/16/2005	300	
MSD	Creve Coeur Cr.@ Mill Bridge Rd.	1703	718340	4285664	6/14/2005	640	
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	8/27/1997	830	1.6
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	10/24/1997	14,000	37.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	12/16/1997	900	2.9
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	2/23/1998	260	6.6
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	3/27/1998	3,500	81.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	6/23/1998	920	10.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	11/30/1998	540	4.6
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	1/31/1999	4,600	787.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	2/10/1999	280	15.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	4/15/1999	4,600	211.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	6/16/1999	1,300	3.3
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	8/2/1999	130	1.8
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	12/9/1999	2,700	97.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	1/5/2000	1,000	3.1
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	2/28/2000	110	5.4
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	5/7/2000	30,000	5580.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	6/19/2000	680	4.6
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	7/31/2000	700	5.4
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	11/6/2000	9,400	86.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	12/19/2000	120	6.8
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	2/28/2001	140	9.8
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	3/15/2001	400	63.3
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	8/28/2001	280	0.92
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	10/10/2001	67,000	42.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	12/10/2001	20	1.97
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	2/4/2002	10	10.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	3/20/2002	360	56.0

Sampling Organization[18]	Site Description[19]	WBID	UTM Easting	UTM Northing	Sampling Date	*E. coli* [20] (#/100mL)	Flow[21] (cfs)
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	5/28/2002	400	7.5
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	8/5/2002	17	1.6
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	10/2/2002	12,000	113.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	12/16/2002	4	2.7
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	2/3/2003	54	4.1
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	3/19/2003	800	117.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	6/24/2003	43	6.8
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	8/11/2003	120	2.7
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	10/9/2003	65,000	353.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	12/16/2003	510	9.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	2/18/2004	37	11.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	3/4/2004	7,600	104.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	5/24/2004	280	12.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	8/4/2004	430	5.2
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	10/5/2004	20	2.7
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	10/12/2004	2,000	64.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	3/22/2005	4,800	249.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	4/20/2005	110	7.8
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	6/20/2005	250	3.6
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	8/10/2005	320	1.1
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	10/5/2005	280	3.2
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	10/31/2005	5,200	80.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	4/2/2006	2,600	96.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	4/3/2006	1,900	13.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	6/6/2006	730	4.5
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	8/23/2006	520	1.2
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	10/2/2006	79	1.4
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	10/16/2006	5,800	27.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	1/17/2007	1,200	9.4
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	2/6/2007	40	3.8
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	3/20/2007	110	7.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	4/3/2007	13,000	73.0
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	4/10/2007	<1	7.8
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	5/21/2007	290	5.6
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	6/18/2007	130	3.9
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	7/23/2007	460	4.9
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	8/8/2007	900	3.4
USGS	Creve Coeur Cr.@Hwy 340	1703	718434	4285664	9/12/2007	480	3.8

Appendix B

Development of bacteria load duration curves

B. 1 Overview

The load duration curve approach was used to develop a TMDL for the drainage area of Creve Coeur Creek. The flow duration curve for this stream was developed using area corrected flow from flow gage data from Creve Coeur Creek. The load duration curve method allows for characterizing water quality concentrations (or water quality data) at different flow regimes and estimating load allocations and wasteload allocations for an impaired segment. The method also provides a visual display of the relationship between stream flow and loading capacity. Using the duration curve framework, allowable loadings are easily presented.

B. 2 Methodology

Using a load duration curve method requires a long time series of flow data, numeric water quality targets, and bacteria data from the impaired streams. Bacteria data, along with the flow measurements for the same date, are plotted along with the load duration curve to assess when the water quality target is exceeded.

A long record of average daily flow data from a gage or multiple gages that are representative of the impaired reach are used to develop the load duration curve. Therefore, the flow record should be of sufficient length to be able to calculate percentiles of flow (typically 20 years or more). If a flow record for an impaired stream is not available, then a synthetic flow record is needed. For this TMDL, flow gage data from Creve Coeur Creek was used, USGS 06935890 Creve Coeur Creek near Creve Coeur, Mo. This gage had an approved daily flow record from June 11, 1997 to Jan. 2, 2011. Data from this gage were corrected for the drainage area of the impaired segment (Table B.1). From this flow record, a flow duration curve was developed (Figure B.1).

Table B.1. Drainage areas of flow gage and the impaired watershed

Location:	USGS 06935890	Creve Coeur Creek
Drainage Area:	22 sq. miles	27.65 sq. miles
Correction Factor:	--	1.2568

The selected TMDL target is multiplied by the flow and a conversion factor to generate the allowable load at different flows. With this load duration curve, the targeted concentration is constant at all flow percentiles. The target concentration used for this load duration curve was the recreation season geometric mean criterion of 206 *E. coli* counts / 100 mL of water, which was applied as a daily target.

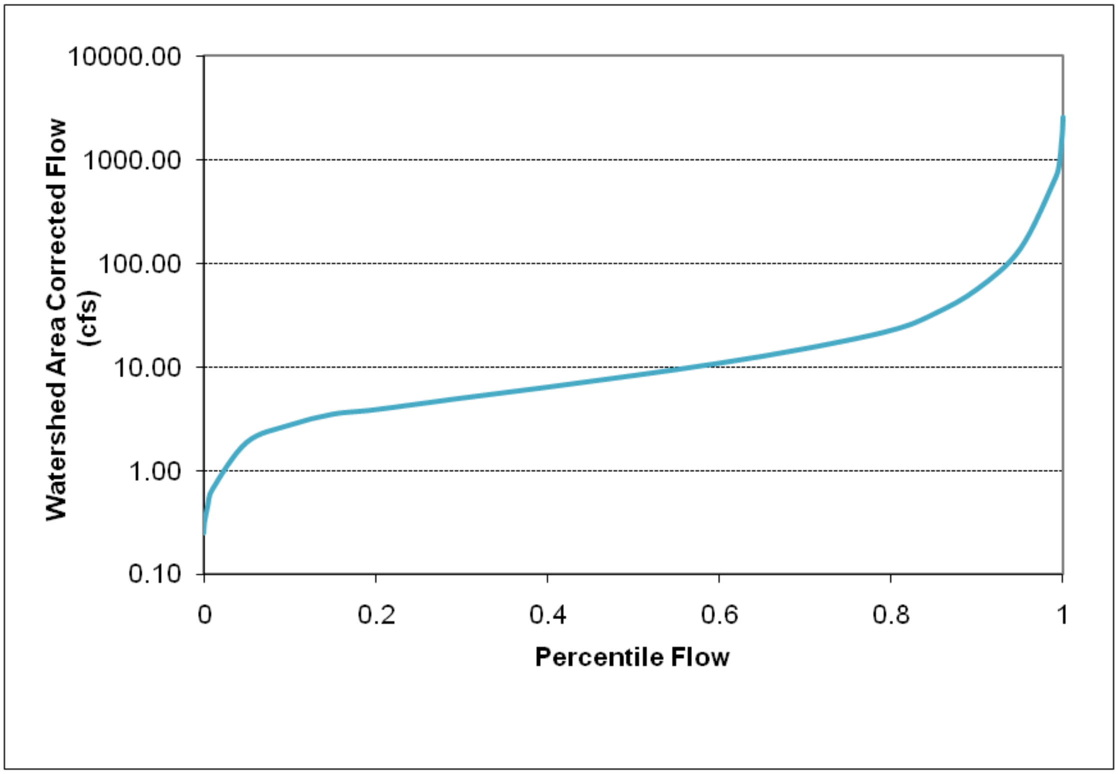

Figure B.1 Flow duration curve for WBID 1703 of Creve Coeur Creek